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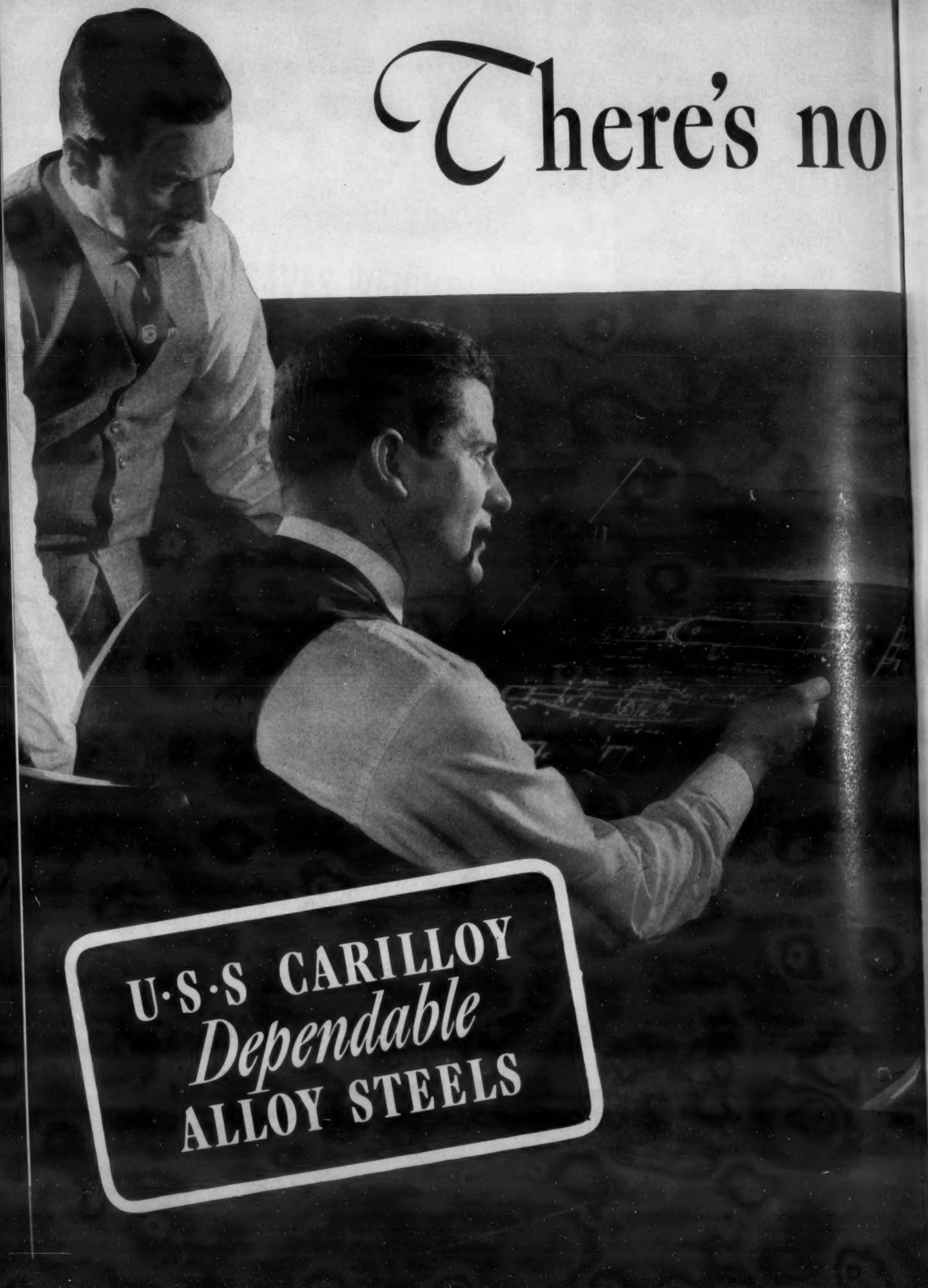
U·S·S CARILLOY
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highlights

Feature Section

The "Mild Alloy" Steels

Some highly interesting comment on the low alloy, high strength ("mild alloy") steels will be found in the first editorial. It is in answer to an advocate of wider use of these steels in the Defense Program. Several phases of this rather controversial subject are discussed.

Induction Hardened Parts

The extent to which the Tocco process of induction hardening of certain tractor parts is contributing to mass production is told in our first article. It is the result of a visit to the plant where the broad application of the process is highly impressive.

High Manganese Steel

The authors of the article on Hadfield manganese steel discuss a new approach to the qualities and use of this old material. They report the results of an investigation for the purpose of employing this steel as a bearing shell in place of carburized and hardened steel. Two methods of increasing the surface hardness are discussed.

Low Alloy Steel Castings

Under normal industrial conditions the production of low alloy steel castings involves the use of certain strategic and critical metals. The author shows how the properties of this type of castings can be maintained by using more readily available materials.

Substitute Solders

Another article which has to do with the strategic metal situation is the one on Substitute Solders. The authors discuss the suitability of cadmium as a partial substitute for tin. Over one-fifth of the tin consumed in this country goes into solders.

Permanent Mold or Die Castings

This concludes the discussion of this subject, the first half of which was published in August. It is of decided interest to design engineers who want information on the properties of the two types of materials.

Engineering Digests

Steel Castings from Down Under

Australian practice in the manufacture of steel castings is reported by Clark (p. 752), who also offers some good advice for casting steel in any country.

Soft Metal Forming Dies

A timely discussion of the use of zinc alloys, rubber and magnesium press tools for forming sheet metal, particularly for aircraft components, is given by McLeod (p. 758).

Weld Cracks

A "composite" on p. 760 explores the causes of "self-cracking" of welds and reveals the expected difference of opinion among authors, one group believing there is no single universal cause, and the other blaming the trouble on parent metal exclusively.

Anodizing Aircraft Parts

American and British practice in the chromic acid anodizing of aluminum alloy aircraft parts is surveyed in a "composite" on p. 774. Again ideas are in collision, some liking their acid kept low and others liking it high.

Atmospheres for Non-Ferrous Heating

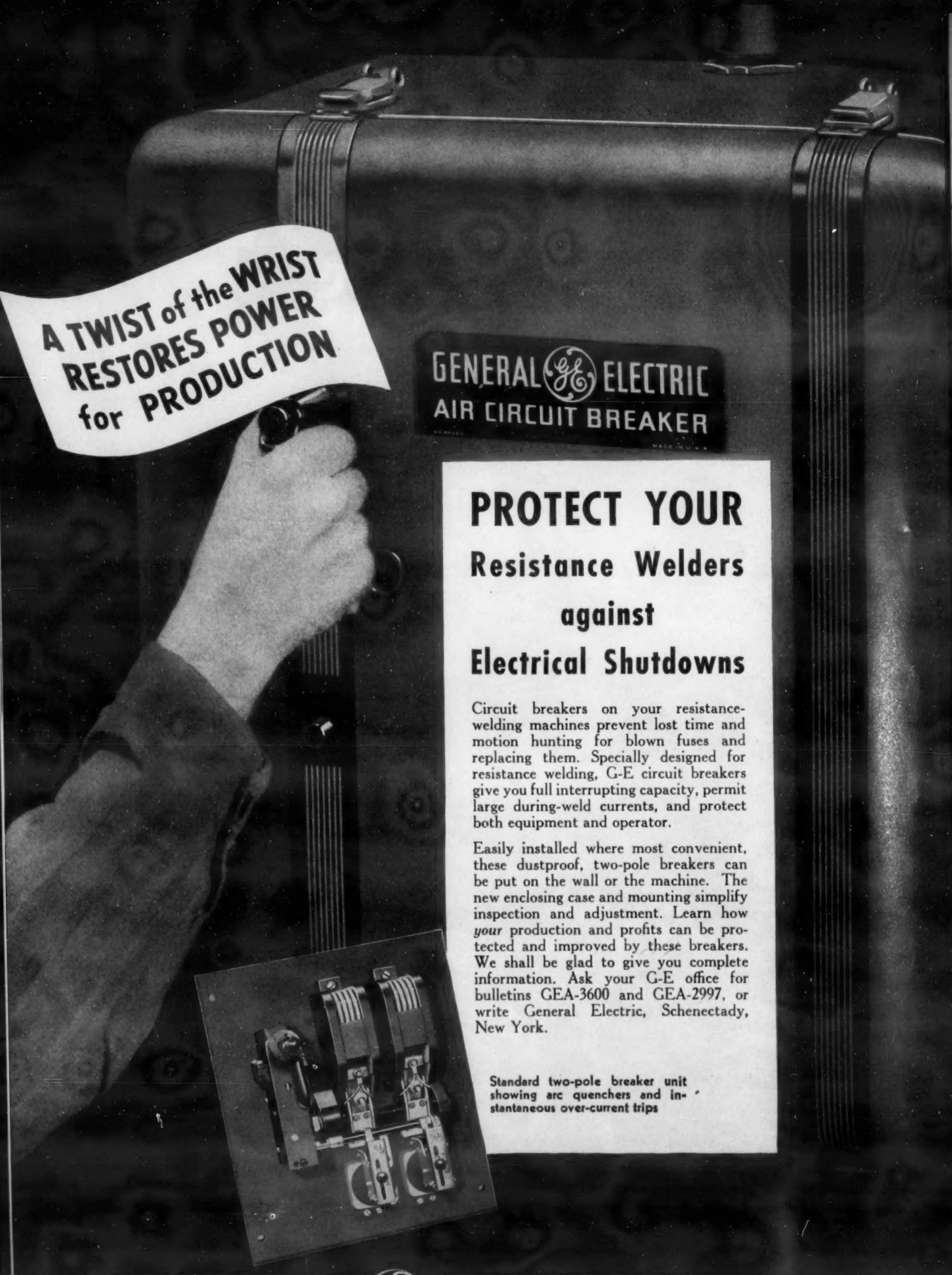
Metallurgical engineers responsible for the quality of non-ferrous metal products at least needn't worry about decarburization during heat treatment. But they do have other special problems, as reported by "Rova" (p. 778). *And for your collection:* Platinum oxidizes slightly in air at low heating temperatures, stays bright at high!

British Cast Irons

A "composite" of recent articles by Pearce (p. 784) reviews British practice in specifying, selecting, alloying and using special service cast irons.

Glass Sealing Alloys

Data on Fernico (iron-nickel-cobalt) glass-sealing alloys for radio tube and electric lamp use are given by Hull, Berger and Navias (p. 792). If you don't know where your next nickel is coming from, however, you should be interested in Kurtz's iron-molybdenum-copper glass-sealing alloys described in the Powder Metallurgy Conference Report on p. 721.



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editorial

Mild Alloy Steels— To Use or Not to Use

Pressure for tonnage in the steel mills and scarcity of alloying elements for the mild alloy steels—the high yield strength, low alloy steels—seem to have reduced the interest of the mills in the development of uses for such steels and to have severely limited their production.

In an article entitled "The Light Weight Development—For Whom and What?" in the August 2 issue of *Railway Age,* F. D. Foote gives the railroads an interestingly worded, good natured scolding for not demanding and using such steel in freight car construction. He points out that 2 lbs. mild alloy steel will do the work of 3 lbs. of plain steel, so that with 8¾ tons of plain steel per car and some 270,000 freight cars to be built in the next couple of years, some 600,000 fewer tons of steel would be needed and some 2½ million fewer tons of ore, scrap, stone, coke, and other raw materials would have to be transported to the blast furnaces and mills. This could be phrased that the capacity thus freed would allow production of some half a million tons of shell steel, on the side, as well as the necessary freight car steel.

For such a saving in production and transportation, the expenditure of the relatively small amount of manganese, copper, phosphorus and chromium that would be needed, seems a small price to pay.

Foote brings up the familiar statistics on the saving the railroads would make by not having to lug around the extra dead weight of the plain steel car over the mild alloy steel car. This isn't a new thought to the railroads; some 50,000 mild alloy cars are in operation, some with over 6 years service. The car builders have the engineering designs for use of mild alloy steel, all they need to do is send blue print B to the shop instead of blue print A.

Qualitatively, and even quantitatively, these facts are not disputed, yet there is more to the situation than is shown by such statistics.

The railroads don't dispute the fact that it takes fuel to lug dead weight around, but they balance that against the facts that the initial cost of the cars, with mild alloy steels priced as they have been under relatively small production, is at least no lower; that freight cars aren't always in motion, and that when they are in motion it is generally on some other line than that of the road which purchased them, and the other line may not be reciprocating by providing light weight cars.

The car designs in use are for cars of the same capacity as those made of plain steel, instead of using the weight reduction to allow more cargo weight with a total loaded weight the same as that of the plain steel car with less cargo. This came about because the first step in trying out the mild steels was to use them with minimum design modification, since the design of a railroad car has to have the approval of various highly conservative and slow moving groups.

The real weight reduction of a freight car is best brought about by a combination of the use of mild alloy steels of weldable grade and the development of shop welding technique for the particular case in hand. Full use of the possibilities has not yet been made in the designs so far approved, hence to go ahead with blue print B without preparing blue print C and getting it approved, is something of a half-way measure.

Foote brings out some of the psychological factors involved. Though each steel company has developed a pet mild alloy steel and sold it, some companies have not been whole hearted in their sales effort, because the substitution of the stronger steel means fewer tons sold, and special scheduling of heats, more or less a pain in the neck to the production gang. Except for one recent semi-killed mild alloy steel, the steels must be killed and hot topped, which necessities are avoided with plain steel.

Foote thinks that the steel makers should long ago have selected two or three of the outstanding types of mild alloy steels and pushed them instead of each one arguing for its own pet. With that point, we disagree, since such selection would have settled upon steels calling for elements that under present conditions are scarce, if not strategic, and valuable experience in handling steels requiring a minimum of such elements would not have been gained. Premature standardization is not a good thing in the long run.

Foote slips one illuminating sentence in. In speaking of evaluation by the railroads of such things as propensity toward denting in service and corrosion-resistant behavior, by long time tests on their own road before definite adoption, he comments that "every railroad feels it must test out the grade produced by each steel company who ships over its line of road." There's a mouthful unsaid there about reciprocal buying and the lead this gives the big company with a lot of widely scattered mills over the single small mill, irrespective of the relative virtues of their respective mild alloy steel. Technology isn't the only thing that counts.

Foote's stressing of corrosion resistance may be in order in the case of freight cars, but, with the good

(Continued on page 718)

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Tractor Parts Rapidly Hardened by Induction

by Edwin F. Cone

The extent to which induction hardening has been applied to the surface of certain steel parts for modern tractor and road building machinery by one large company, and the speed which has been attained, are told in this article.

The Caterpillar Tractor Co., Peoria, Ill., has probably, more extensively than any other company, applied the "Tocco" surface hardening induction process. More than 90 parts which enter into this company's products are thus heat treated. The speed and other claimed advantages are emphasized as well as the contrast between this modern process and the older or carburizing methods.

Induction hardening can be a potent factor in some present manufacturing processes in attaining faster production for defense.

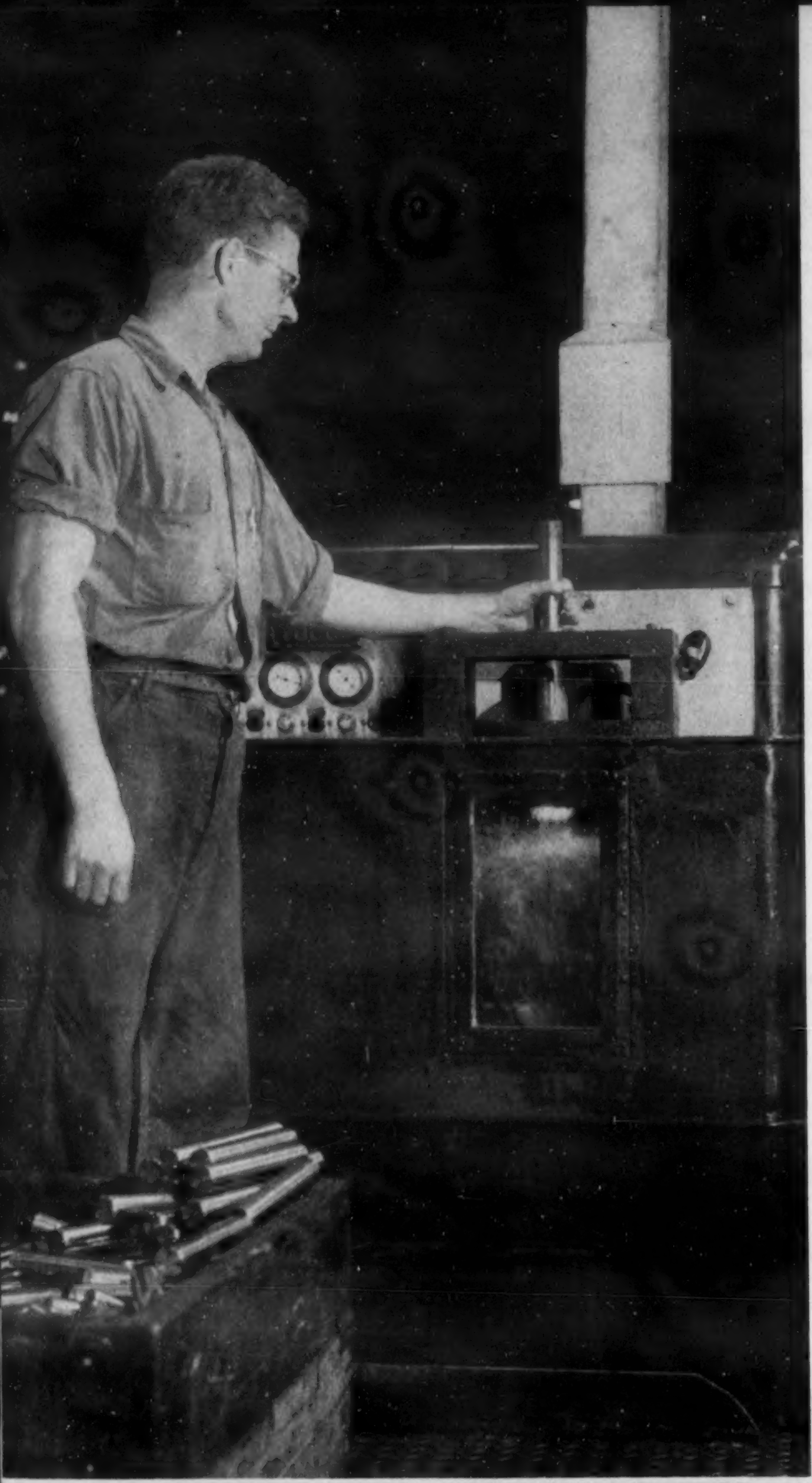
DEVELOPMENTS IN THE HEAT TREATING of steel have been so rapid in recent years that some of the results border on the revolutionary. New furnaces, new heat-treating methods and cycles, and new ideas have rapidly come to the front. The results have been both numerous and striking—better products, faster heat treatment and mass production.

Prominent among these developments has been surface heat treating or hardening by induction heating. Most of those who read this article are familiar with its principles—rapid heating of the surface of the steel product by electric heat induced by high-frequency electric current and immediate quenching with water. One of the first descriptions of this was the article in the January 1938 issue of METALS AND ALLOYS, page 1, entitled—"Crankshafts and Other Parts Surface Hardened by Induction Heat."

The leader in this field has been the Ohio Crankshaft Co., Cleveland, whose process and equipment are familiarly known as the "Tocco" process. The use of this process and equipment has spread rapidly

BELOW:

Tough work where proper heat treatment counts. A Caterpillar diesel D8 tractor with Le Tourneau bulldozer leveling fill in hospital area of one of the cantonments.



A track pin going through the induction hardening machine. Note whitehot pin behind the glass and the quenching water spray.

to many companies and to many products. One of the most extensive users of the process is the Caterpillar Tractor Co., Peoria, Ill., a producer of Diesel engines, track-type tractors and road machinery of many models and sizes.

Scope of the Application of the Process

This process of rapid surface hardening of certain steel parts was first applied by this company to track pins for Diesel tractors of many sizes, but its use has now extended to many other parts entering into the construction of the engines, tractors and road machines. The first use started in 1939 when a 150-kw., 2000-cycle motor generator set was installed for hardening track pins. Since then there have been added two 500-kw., 3000-cycle sets; one 600-kw., 3000-cycle set and also 1140 kilowatts in other equipment of higher frequencies, a total of 2740 kw.

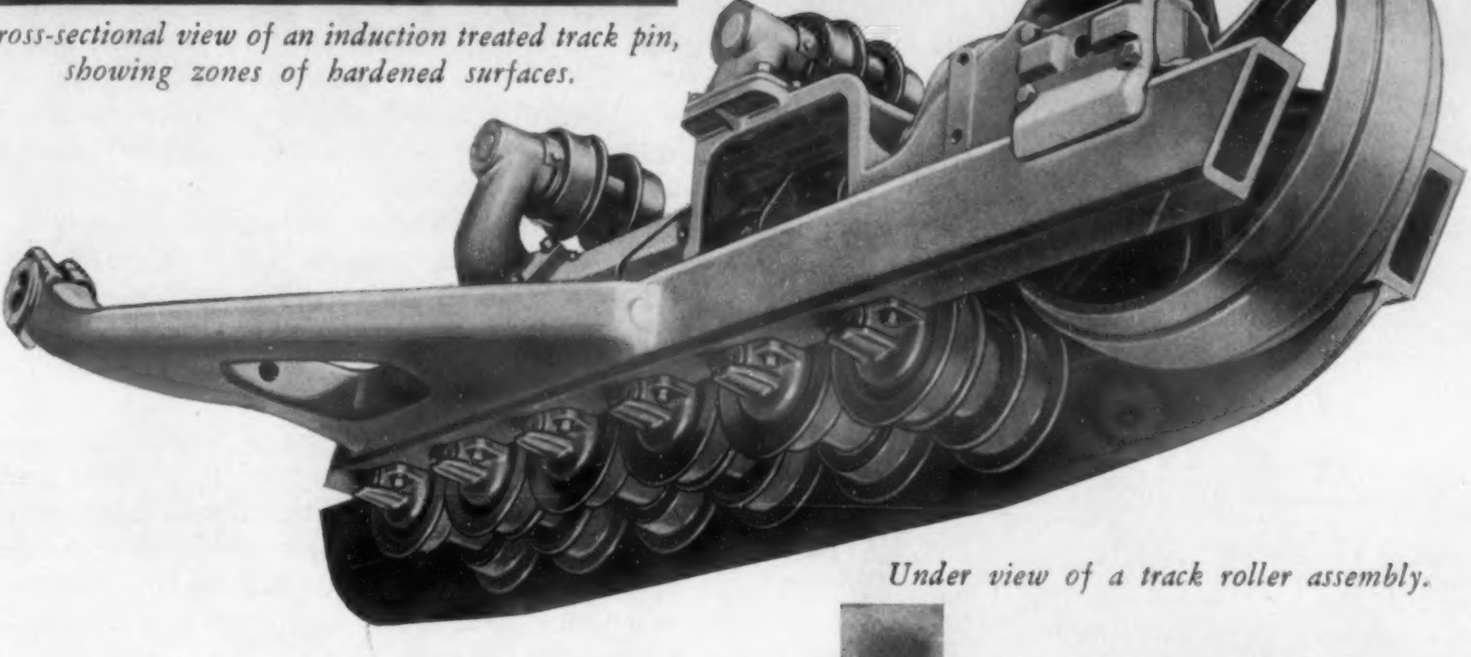
Besides the hardening of the bearing surfaces of all crankshafts, the Caterpillar company is now treating track pins, track sprocket shafts, pivot shafts, track roller shafts, track carrier roller shafts, front idler shafts, steering clutch control lever shafts, water pump shafts, transmission gear shift shafts, power control clutch shafts, track rollers with double and single flanges, rocker arms, plungers and chain drive sprockets.

It is the purpose of the rest of this discussion to describe in some detail the heat treatment of three

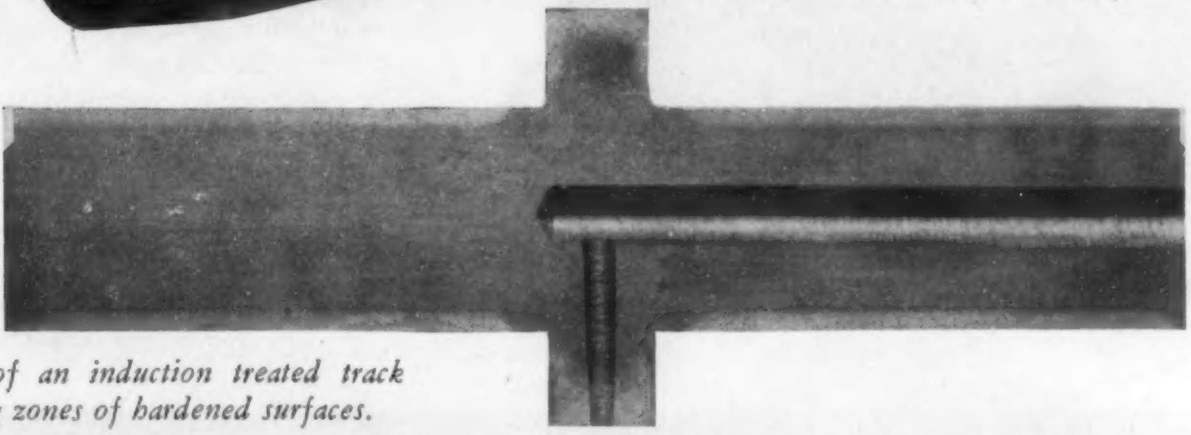
Induction hardening equipment in one of the buildings, showing two track pin hardening units in the background with control panels and shaft hardening unit in the foreground.

TOCCO
TEST PIECES

Cross-sectional view of an induction treated track pin, showing zones of hardened surfaces.



Under view of a track roller assembly.



Cross-sectional view of an induction treated track roller shaft, showing zones of hardened surfaces.

important parts of the company's products—track pins, the track roller shaft, and the motor grader tandem drive sprocket.

Track Pins

These pins are an important part of the crawling mechanism, holding the track links together. The steel is S.A.E. 1050 "as turned" hot rolled bar stock. It is selected on the basis of its hardenability, a minimum of Rockwell "C" 64 required from a critical quenching rate. The bars, of various diameters, are cut into specified lengths and are then ready for heat treatment in the Tocco machines.

Two of these machines are operated in parallel off the same generator, drawing about 350 kw. at 3000 cycles. For example, pins of 1-5/16 in. and 1¾ in. are fed into the respective machines, one pin right after another. The power always stays on and it is stated that they were the first production machines for surface hardening steel progressively, i.e. as compared with impulses, single "shot" heating.

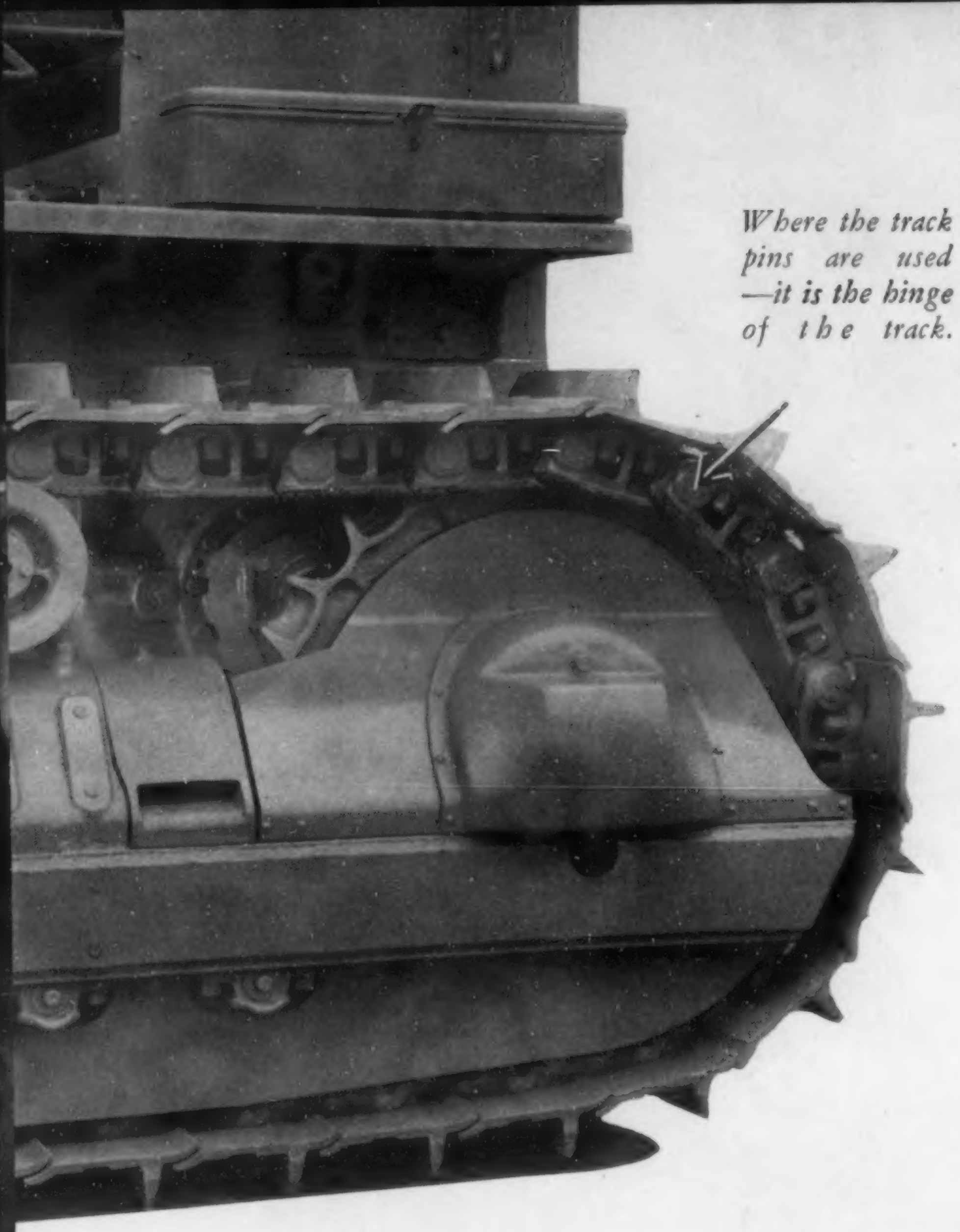
The 1¾ in. pins 11 in. long, pass through the machines at the rate of 225 per hr. and the 1-5/16 in. pins 416 per hr., and in each instance are fully surface-hardened. For the former the time consumed is 15 sec. each and for the latter 10 sec. The 1¾-in. pins weigh 9 lbs. each. Each hour about 1 ton of the 1¾-in. pins and about 1,500 lbs. of the 1-5/16-in. pins pass through the machines. The depth of hardness is about 0.140 ± 0.010 in. The Rockwell C hardness on the surface is 63 to 67.

To visualize the speed and mass production achievement of these machines, the company states that during the first six months of this year 6,000,000 lbs. at the rate of 500 tons per month of track pins have been surface hardened. By contrast, the old method of surface hardening these pins was the conventional pack carburizing process which consumed 36 hrs. per batch of pins—a decided contrast.

Track Roller Shafts

The track roller shaft is an important part of the tractor propelling mechanism. It is an upset forging, made from hot rolled bar stock, with a protruding flange in the middle. One of the illustrations shows a cross section "as hardened."

The steel used in these roller shafts is S.A.E. 1045, annealed prior to machining. The handling of these in the Tocco machines is not so simple as in the case of the track pins—three operations are required to surface harden them. First, the flange is



Where the track pins are used —it is the hinge of the track.

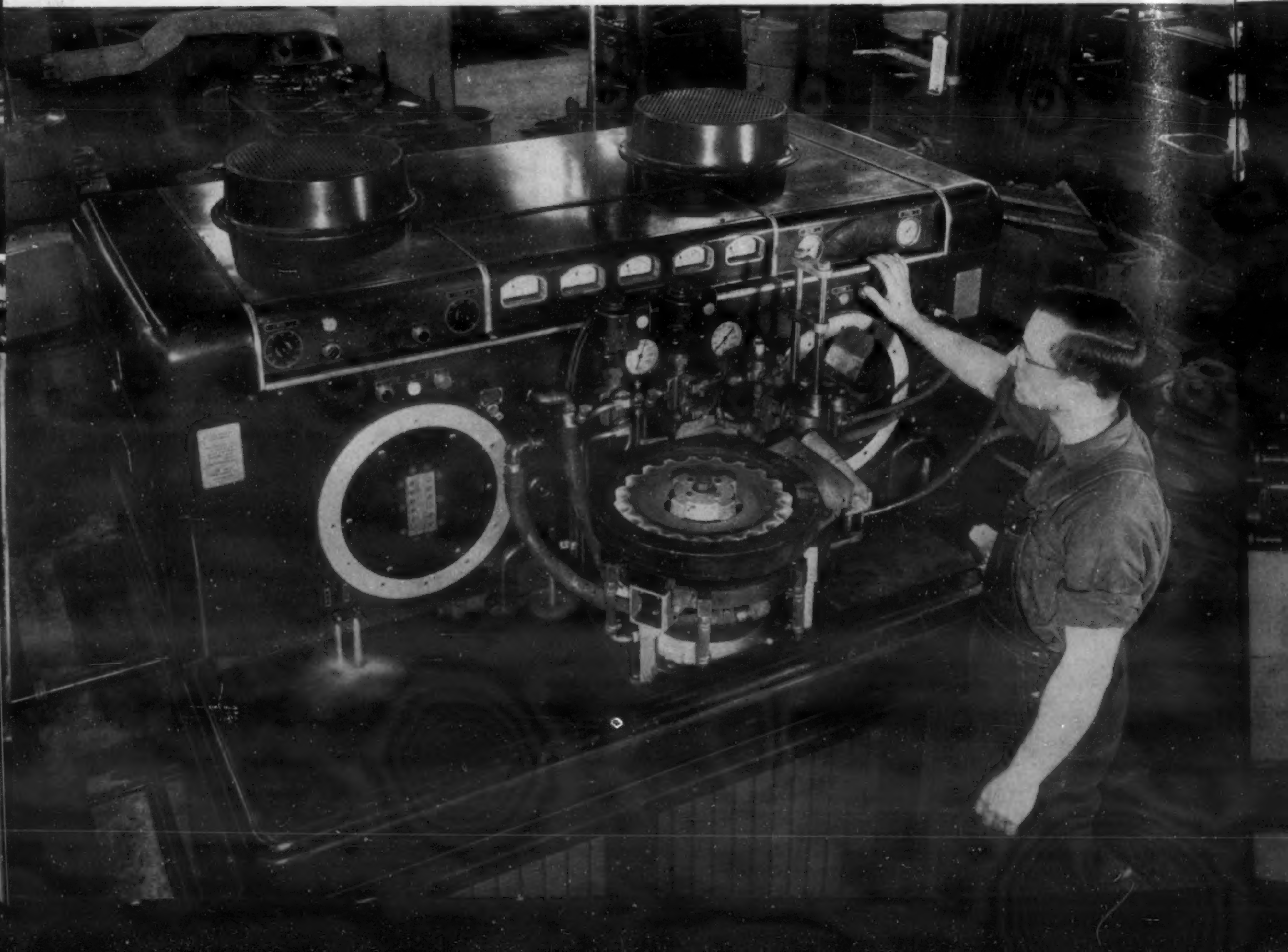
treated, eight at a time in one machine, heating the flange from the outside diameter and quenching only the thrust faces. In another machine each of the two bearings are treated, the whole operation being done with single impulses. The current input for the eight flanges is 240 kw. and for the shafts it is 200 kw. To harden the flanges of the shafts requires 1½ min. or 12 sec. each and to treat each bearing, 5 sec.

Before the induction method was adopted these roller shafts were made of S.A.E. X 1020 (0.15-0.20 C) and were carburized and hardened, all this involving some 36 hrs.

Sprockets

The induction hardening of the motor grader tandem drive sprockets differs from that just described for the other two parts and is an outstanding operation. In this instance you have a circumference of an entirely different outline than in the case of the pins or the roller shafts. The circumference to be hardened is varied in contour; it is not simply

The Tocco apparatus for heat treating and hardening a tandem drive sprocket used on motor graders. The outer edge of the sprocket is up to heat ready for water quenching.



cylindrical in shape but is analogous to a wheel with teeth, the undulating or wavy surface of which must be hardened. It is also a fact that current of higher frequencies is necessary for parts of this shape.

The sprockets are upset forged from round stock and S.A.E. 1040 steel is employed. There is one Tocco machine for this operation with the inductor so made that the periphery of the sprocket is heated and then immediately water quenched. The heat input for this part is 40 kw. at 9600 cycles and it takes about 85 sec. to bring the periphery to be hardened up to temperature for quenching. The machine is 80-kw. self contained. In this example the finished hardness is 57 to 62 R. C. and the depth of hardness 0.140 to 0.180 in. The bore of the sprocket is of course machined before hardening, reamed afterward, thus saving expensive grinding. In this treatment the process is so rapid that the sprocket does not warp or distort appreciably. About 25 to 30 sprockets can be hardened on the periphery per hour.

Many Parts Hardened

The hardening of the track pins, the roller shafts and the sprockets, above described, are representative of the 90 or more parts which are thus surface hardened. The company lists among the advantages derived from the use of this process—minimum distortion, maximum hardness, no scaling, localization of the heating, and *speed*. Plans are on foot to apply the induction processes to other parts more complicated in design.

The company also has one machine for hardening the inside surface of cylindrical parts by the Budd induction heating process. It is applied to alloy cast iron cylinders for Diesel engines. This was fully described in an article in METALS AND ALLOYS, June 1941, page 713, entitled—"Induction-Hardened Cylinder Bores."

Expanding Use of the Process

Some idea of the extent to which the Tocco process has been and is being used by the "Caterpillar" company may be gleaned from the fact that in 1940 the company treated about 55,840,000 sq. in. of various parts, exclusive of the crankshafts, by the Tocco process. During the first 6 months of this year, there has similarly been treated 52,177,940 sq. in.—indicating the expanding scope of its use. This is over 8,696,323 sq. in. per month in 1941 as compared with 4,653,000 sq. in. monthly in 1940, an increase this year of about 87 per cent.

Part of the equipment used for hardening crankshaft bearings by induction heating.

Hadfield Manganese Steel

Another Approach to Its Qualities and Use

By V. R. FARLOW and L. H. McCREERY

Metallographers, Caterpillar Tractor Co., Peoria, Ill.

This article offers a report on the results of an investigation of Hadfield's manganese steel for the purpose of employing it as a bearing shell in place of carburized and hardened steel.. The idea, say the authors, was a desire to see if they could form the shell and cold-work it sufficiently to raise the hardness on the surface so that it would resist abrasion against a hardened shaft and such abrasive material as might gain access from service conditions.

Two alternate methods of increasing the surface hardness were suggested: Pulling a burnishing broach through the two shells confined in a "pot," or by rotating a mandrel with multiple hammers called a "Borizing" tool. A metallographic investigation was made to see what effect on the phase change the two methods might offer.

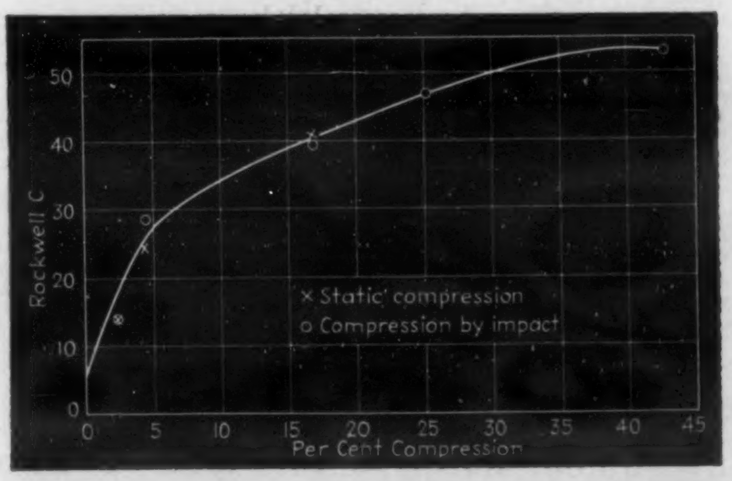
The interesting thing about this report is the fact that, by the use of the electrolytic polish, the metallographers were able to maintain the structures as cold worked without disturbance by mechanical polishing.

These quantitative controls of the use of an old material in new applications by proper manipulation may be worth something to others engaged in the art of metal fabrication. One of the principal reasons for carrying on this work, says G. C. Riegel, chief metallurgist, under whose direction the investigation was made, is the difficulty of maintaining size in thin-shelled bearings carburized and hardened. —The Editors.

When a hard bearing surface is required to operate against a hard shaft, that is, in using, in a sleeve bearing, materials analogous to those in ball and roller bearings, the warpage and other difficulties connected with the use of a carburized and hardened bearing shell make it desirable to consider other possible materials. One such possibility lies in work-hardening austenitic steel. Two possible ways of work hardening are apparent. The formed half-shells could be confined in a "pot" and a burnishing broach pulled through to compress the surface layer, or a "Borizing" tool, a rotating mandrel with multiple hammers, could be inserted and the compression produced by repeated impact, with much the same effect as is produced by shot-blasting.

Niconoff[1] strain hardened conical specimens of wrought 1.10 per cent C, 12.5 per cent Mn steel, of about 9 Rockwell C as quenched from 1920 deg., by impact upon the tip, securing about 50 to 55 Rockwell C as the maximum in the most severely deformed material, which is about the range reported by several earlier investigators.

Fig. 1.



To determine the hardening produced by static compression and by repeated impact, wrought manganese steel strip 6 in. wide by 1/4 in. thick, of 1.15 per cent C, 11.6 per cent Mn was cut into 1/2 by 1/2 in. specimens which were ground on both faces to 0.237 in. thick. The specimens were reduced in thickness by 5, 10, 40, 60 or 100 thousandths, or about 2, 4, 17, 25 and 42 per cent. All five reductions were made by impact, the specimens were placed between steel plates and the sandwich hammered down to the desired reduction. The first three reductions, 2, 4 and 17 per cent were also produced by static loading under compression in a testing machine with a cross-head speed of 0.05 in. per min.

The cold-worked specimens were tested for surface hardness and, on the sectioned surface after cutting under coolant with an abrasive wheel and polishing electrolytically to remove any influential effect of the cutting operation, Rockwell 30/T and 30/N measurements were made. These have been converted to Rockwell C and are plotted in Fig. 1.

Within the errors of measurement, the surface and center hardnesses were the same. The structure at the center is shown at 1,000 X in Fig. 2 for the material in its original, soft-quenched condition, in Figs. 3, 4 and 5 for increasing deformation by static loading, and in Figs. 6, 7, 8, 9 and 10, for increasing deformation under impact. Like deformation produces like hardness and structure, irrespective of which method of compression was used. At 42 per cent deformation (Fig. 10) the hardness rose to over 50 R. C. To harden the material sufficiently for the purpose in mind, deformation of somewhat more than 25 per cent would be required.

The precipitation of carbide needles at the center of the specimen upon heating the 1/2 by 1/2 by 0.237

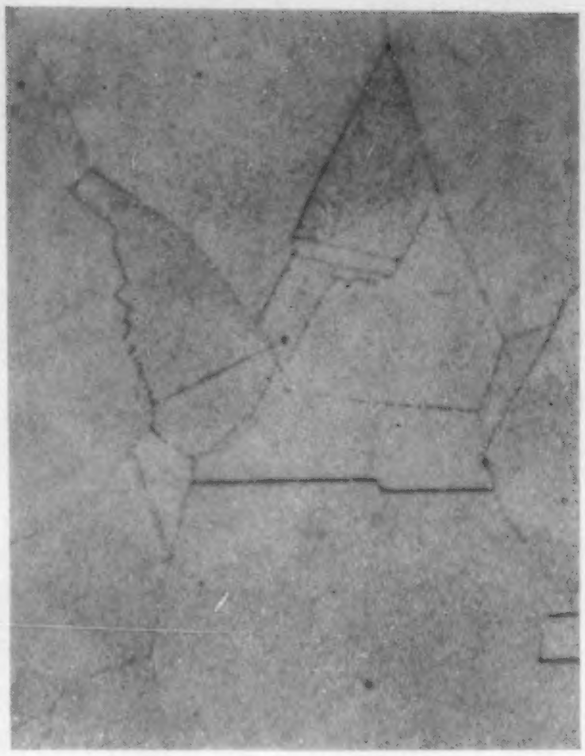
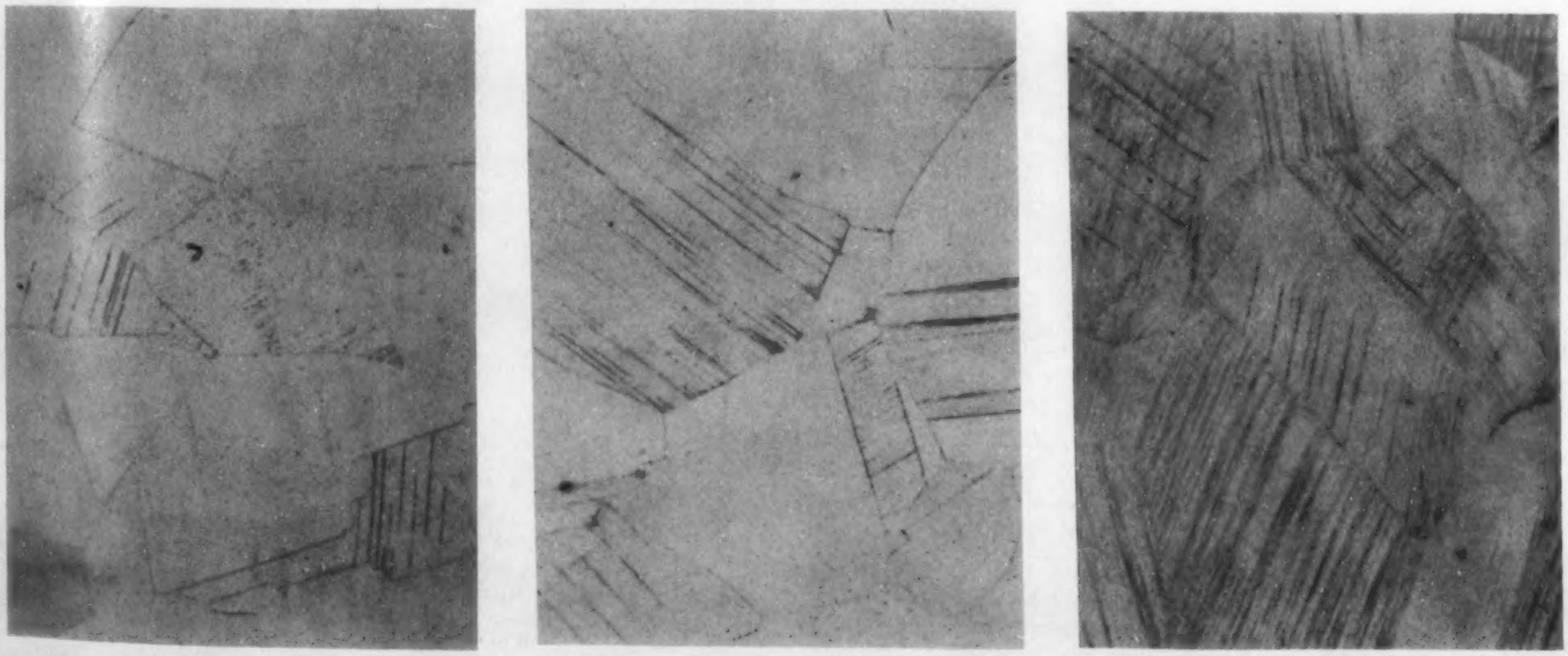


Fig. 2. Material as received. Structure at the center. 1,000X. Converted Rockwell C hardness: Surface, 4; center, 7.



Figs. 3, 4 and 5. Material compressed by static loading. Fig. 3 (left) 2.1% compression; converted Rockwell hardness: Surface, 12; center, 16. Fig 4 (center) 4.2% compression; converted Rockwell C hardness: Surface, 24; center, 25. Fig. 5 (right) 16.8% compression; converted Rockwell C hardness: Surface, 40.5; center, 40.5. All 1,000X.

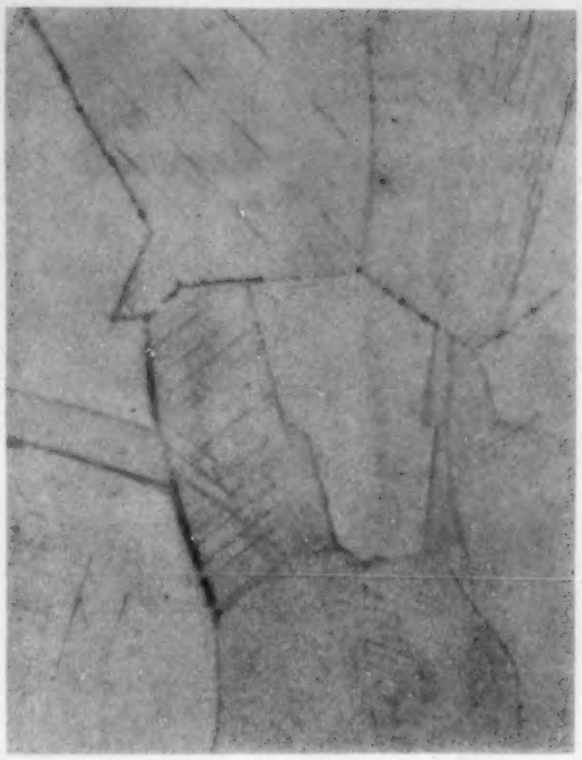


Fig. 6

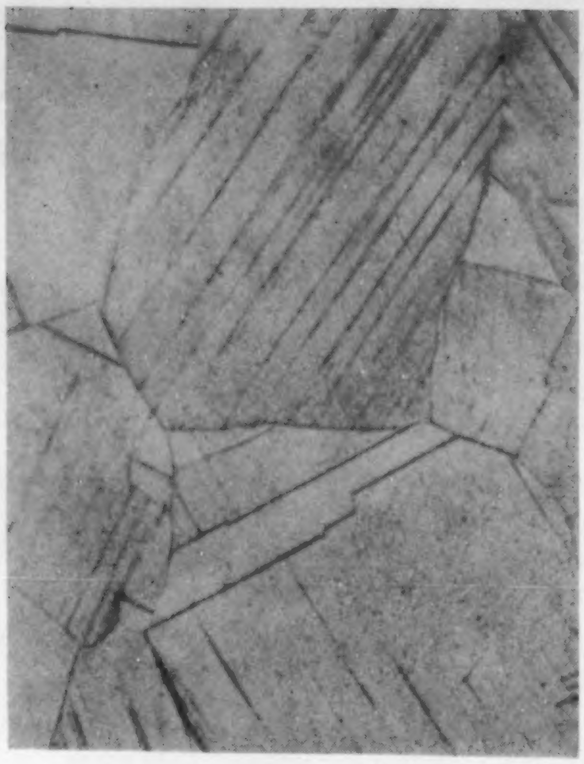


Fig. 7

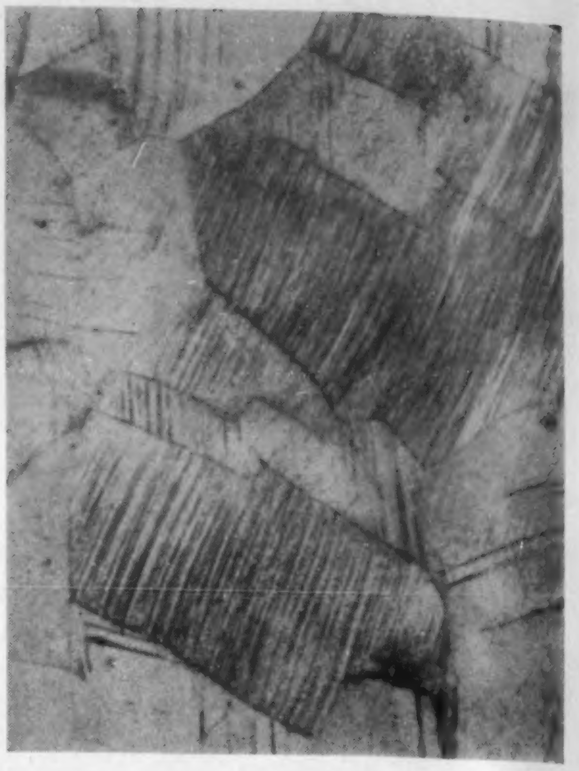


Fig. 8

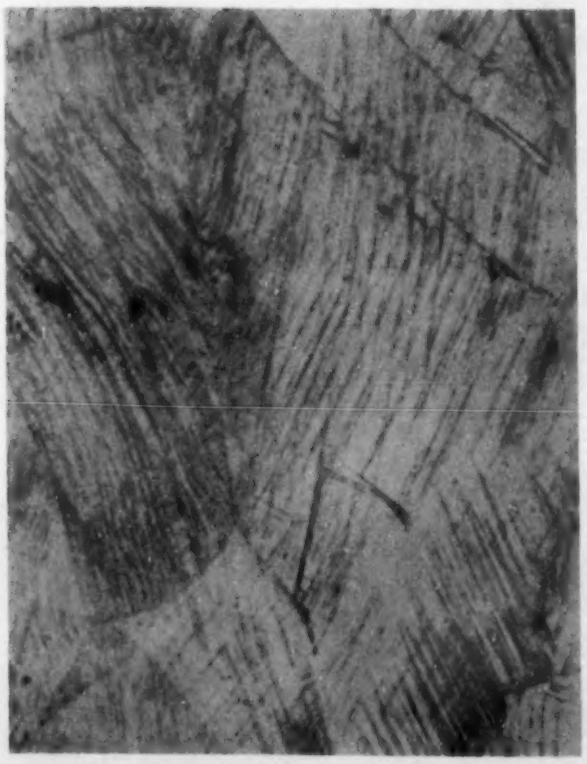


Fig. 9

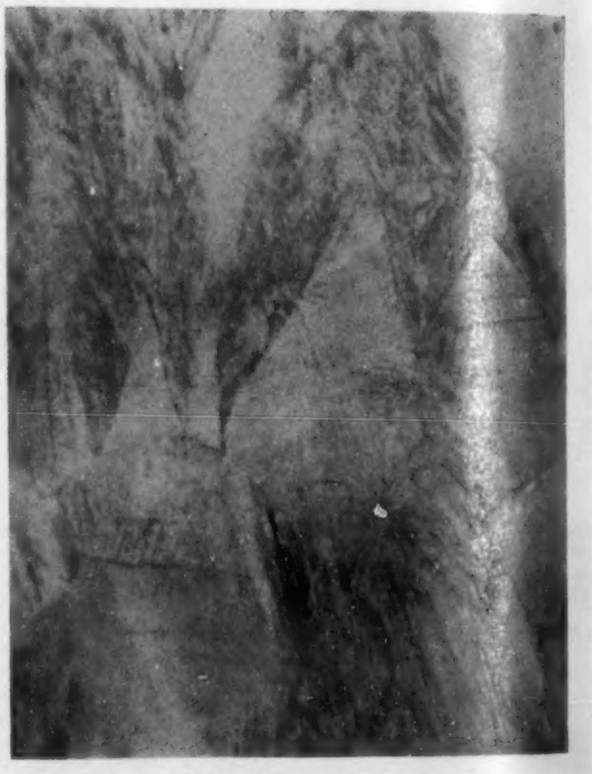


Fig. 10

Figs. 6, 7, 8, 9 and 10. Material compressed by impact loading. Fig. 6—2.1% compression; converted Rockwell C hardness: Surface, 12; center, 16. Fig. 7—4.2% compression; converted Rockwell C hardness: Surface, 28.5; center, 28.5. Fig. 8—16.8% compression; converted Rockwell C hardness, surface and center, 39.5. Fig. 9—25.3% compression; converted Rockwell C hardness, surface and center, 47. Fig. 10—42.1% compression; converted Rockwell C hardness, surface and center, 50.5. All 1,000X.

in. specimens at 800 deg. F. for 1 hr. and air-cooling is shown in Fig. 11, that by following that treatment with a second 800 deg. (2 hr.) air-cooling treatment, in Fig. 12. The surface remained soft and practically free from carbide precipitation, while the center jumped to 23 and 35 R. C. in the two cases.

When the specimen, cold worked 4 per cent, was heated at 800 deg. for 1 hr. and air-cooled, the center showed 35 R. C. and the surface (see Fig. 13) 22 R. C. The one cold worked 17 per cent, similarly treated, showed however, 44 R. C. at both center and surface (see Fig. 14), indicating a greater readiness to precipitate carbide with increased cold-work. The difference between surface and center hardness in the case of the specimen cold worked 4 per cent, and the agreement between center and surface hardness of the one cold worked 17 per cent reflect the change in critical cooling rate required to prevent carbide precipitation.

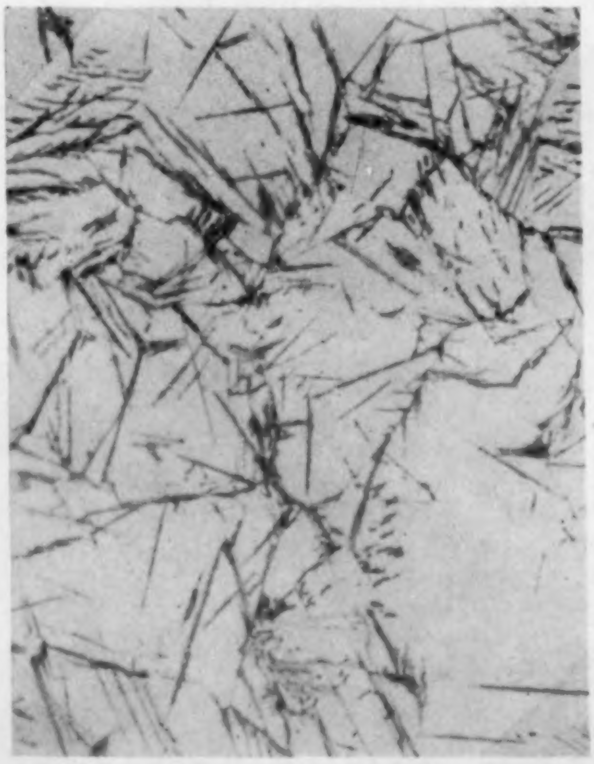
Thus in the unworked material, the material is given a certain propensity towards carbide separation, i.e., has a certain critical cooling rate that depends on the time it has been held at temperature, but in both cases (Figs. 11 and 12) the surface cools enough faster than the center to pass through the temperature zone of precipitation without precipitation occurring. When the material has been cold-worked 4 per cent before heating at 800 deg., the critical cooling rate has been changed enough to cause the surface to harden somewhat, i.e., for some carbide precipitation to occur, though more hardening and more precipitation occurs at the slower cooling rate of the center.

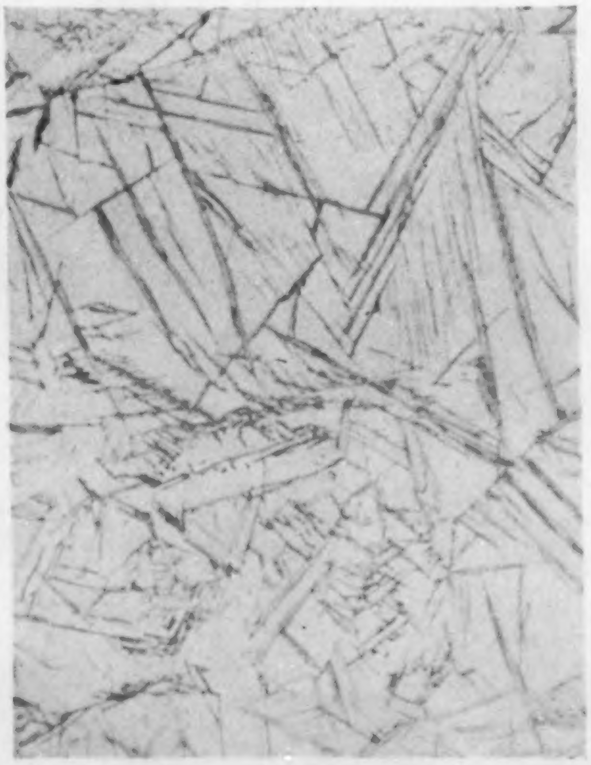
When the steel is cold worked 17 per cent, the propensity towards separation of carbide is so great that the more rapid cooling rate at the surface is no more effective than the slower rate at the center, at either rate there is profuse precipitation. It is, of course, to avoid precipitation that austenitic manganese steel is quenched from around 1,850 deg. or above.

That 800 deg. is just within, or close to, the upper zone of temperature at which carbide precipitation occurs in unworked material is shown in Figs. 15, 16 and 17, all at 100 X instead of 1,000 X as was the case with the previous figures. Fig. 15 shows the original material, corresponding to Fig. 2. Fig. 16 shows that, although the hardness is not appreciably increased, a little carbide precipitation has occurred at 800 deg. or occurs even under the rapid cooling rate secured by quenching the small specimen in iced brine. The slightly slower cooling rate at the center produced when quenching into water, as Fig. 17 shows, gives a little more carbide separation and a just perceptible increase in hardness. Slowing down the cooling rate to that in air, makes the surface of the small specimen cool at the same rate as the center did on the water quench, and it remains relatively soft, while the center of the air cooled, unworked specimen, hardens to 23 R. C.

Few precipitation hardening phenomena are as

Figs. 11 and 12. Tempering the unworked austenitic structure. Fig. 11—Heated at 800 deg. F. for 1 hr., cooled in air; converted Rockwell C hardness: Surface, 9; center, 23. Fig. 12—Heated at 800 deg. F. for 1 hr., cooled in air, heated again at 800 deg. F. for 2 hrs., cooled in air; converted Rockwell C hardness: Surface, 9; center, 35. Both 1,000X.





grossly sensitive to cooling rate as is the austenitic manganese steel. Duralumin, though its properties and microstructure are not appreciably different whether it is quenched in hot water or cold water, is quite susceptible to intercrystalline corrosion when quenched in hot water, and quite resistant to it when quenched in cold water. In the present case the microstructure records the cooling rate in highly sensitive fashion.

In order that the microstructure of austenitic manganese steel may be examined with assurance that the observed structure correctly represents the material, it is necessary to avoid cold working the surface during metallographic polishing. Some illustrations of supposedly unworked material published in the literature appear much like Figs. 3 or 6, with slip lines resulting from the polishing pressure. To get below the worked layer, it is necessary to etch so deeply that the surface becomes unduly roughened, so metallographers have had to compromise, with the result that the micrographs may not precisely represent the real structure.

The dilemma can be avoided, and has been avoided in the micrographs shown, by rough polishing in the initial stages as usual, then by means of electrolytic polishing, removing the cold-worked layer without roughening the surface. The usual final etch is then used.

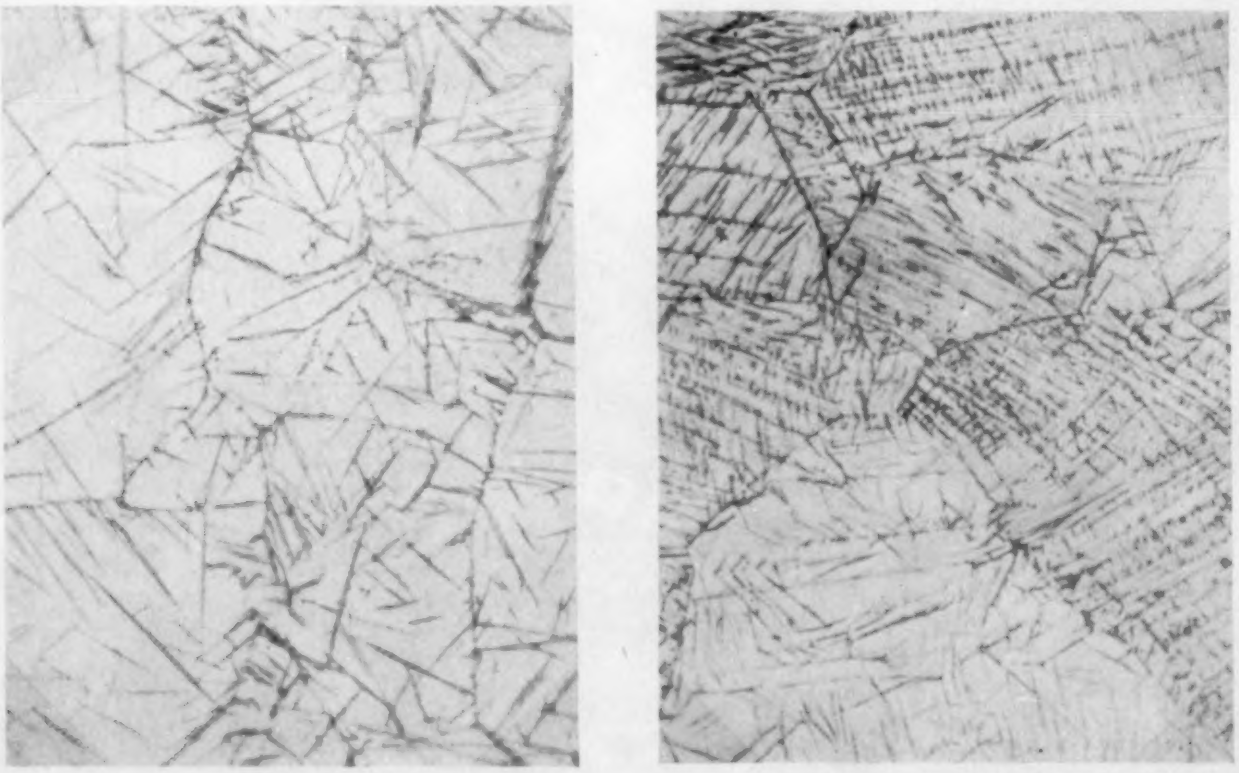
The micrographs shown are on surfaces electrolytically polished in 382 cc. acetic anhydride, 92 cc. perchloric acid, 25 cc. water, for $\frac{1}{2}$ min. at 40 volts and 2 amps. per sq. in. current density, and then etched for 3 sec. by immersion in 5 cc. hydrochloric acid and 1 g. picric acid, 100 cc. 95 per cent ethyl alcohol.

[It should be stated that all Rockwell hardnesses below "C" 20 have been extrapolated by conversion from Rockwell "30 T" values for simplification in making comparisons. From a strictly scientific standpoint this is not in keeping with the correct use of the particular hardness testing instrument used.—Editor.]

Reference

[1] D. Niconoff. "Quantitative Measurement of Strain Hardness in Austenitic Manganese Steel," *Preprint No. 15*, Am. Soc. Metals, 1940, 19 pages.

Figs. 13 and 14. Tempering the cold-worked structure. Fig. 13—Compressed by 4.2% by static load, then drawn at 800 deg. F. for 1 hr., and air cooled; converted Rockwell C hardness: Surface, 22; center, 35. Fig. 14.—Compressed by 16.8% by static load, then drawn at 800 deg. F. for 1 hr. and air cooled; converted Rockwell C hardness: Surface and center, 44. Both, 1,000X.



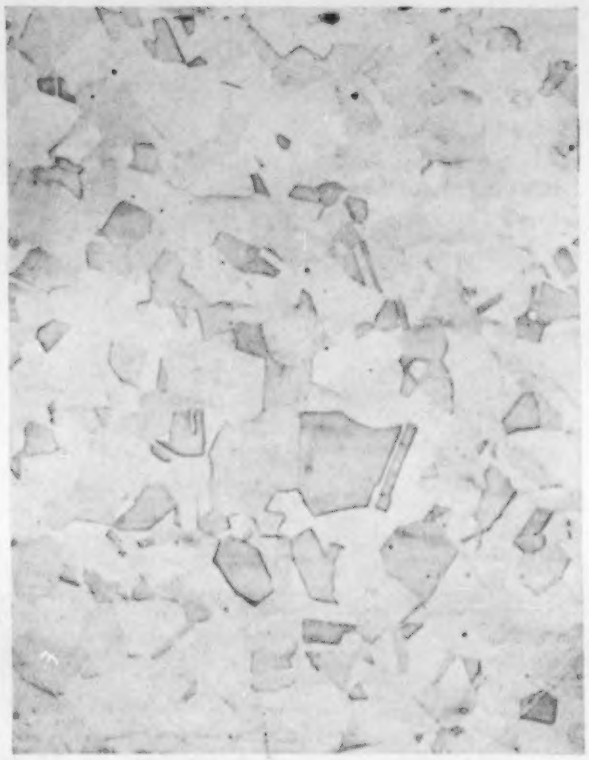


Fig. 15

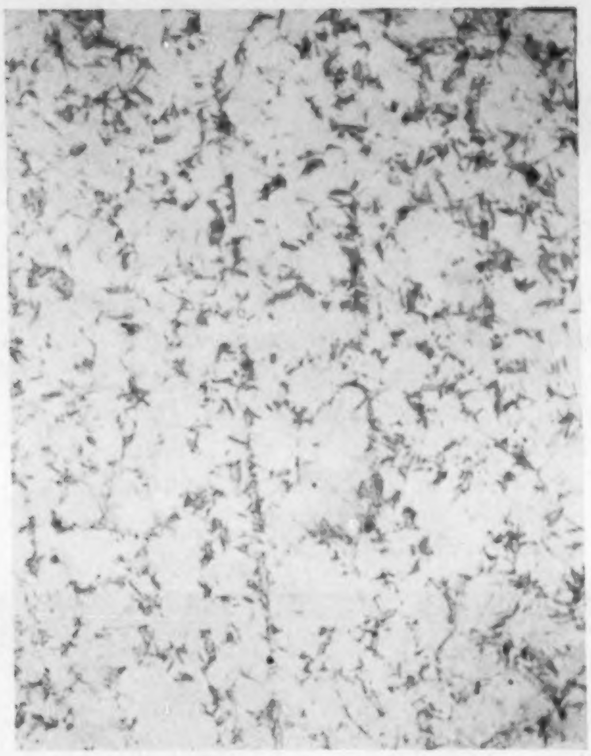


Fig. 16

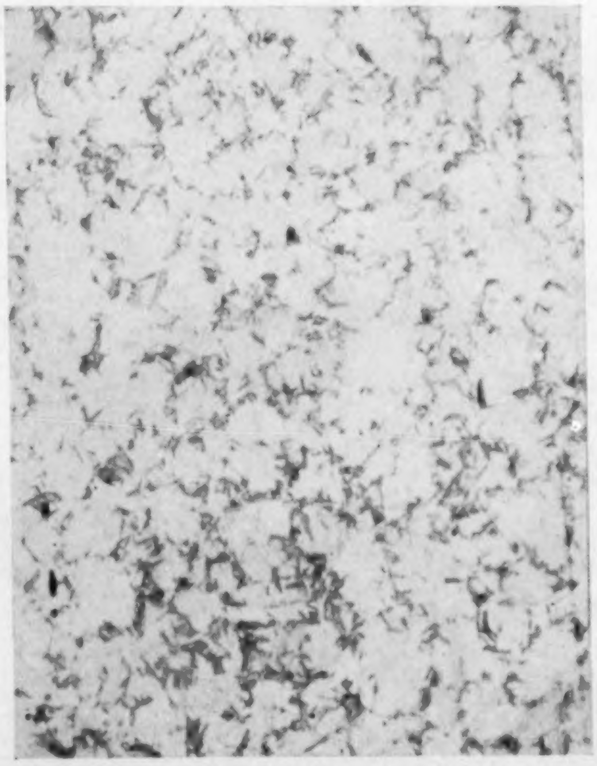


Fig. 17

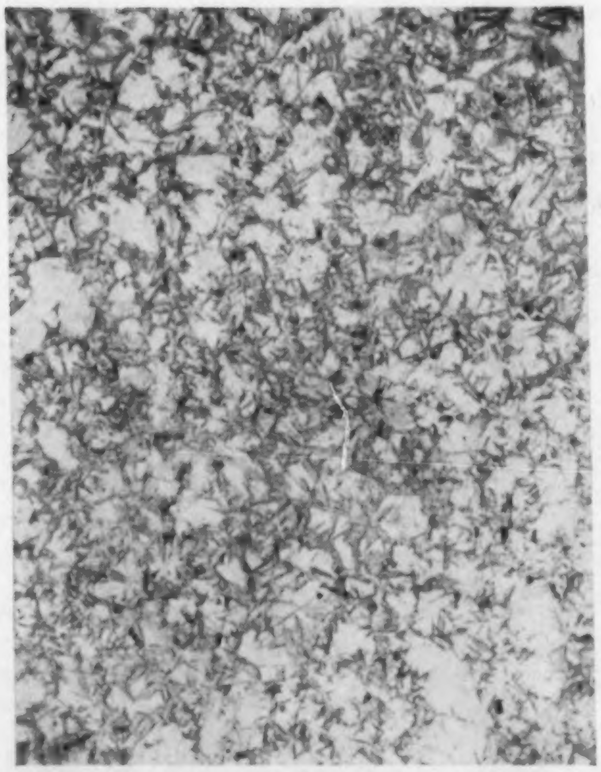
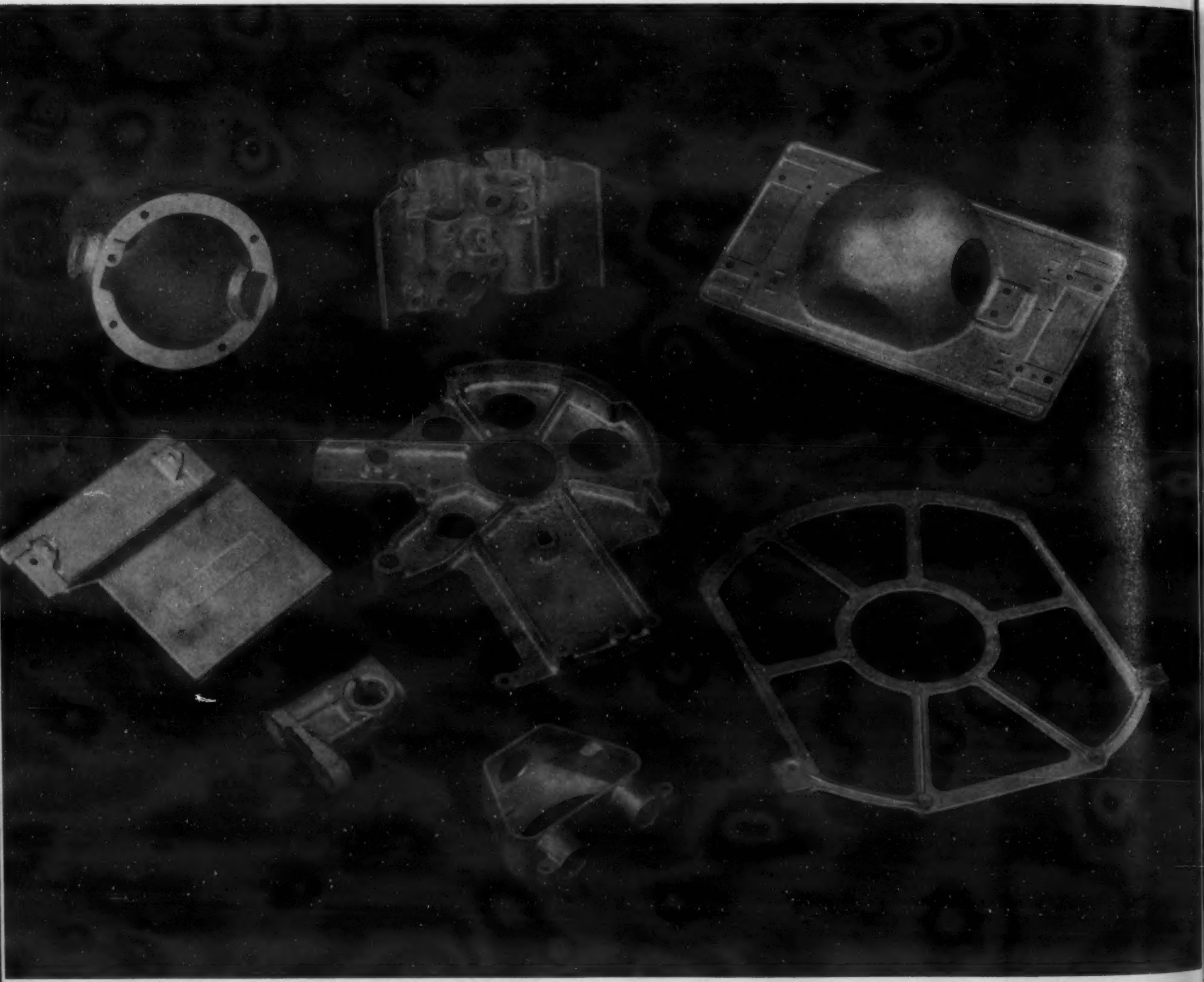


Fig. 18

Figs. 15, 16, 17 and 18. Effect of rate of cooling from the tempering temperature. Fig. 15.—As received; converted Rockwell C hardness: Surface, 4; center, 7. Fig. 16.—Heated at 800 deg. F. for 1 hr., quenched into iced brine (10% NaCl) at 28 to 32 deg. F.; converted Rockwell C hardness: Surface and center, 7. Fig. 17.—Heated at 800 deg. F. for 1 hr., quenched into water at 70 to 80 deg. F.; converted Rockwell C hardness: Surface, 7; center, 9. Fig. 18.—Heated at 800 deg. F. for 1 hr., cooled in air; converted Rockwell C hardness: Surface, 9; center, 23. All 100X.

Permanent Mold and

Group of die castings in aluminum alloy, fairly typical of many in general production. Some of them could be produced in permanent molds, but not with dimensional tolerances quite so close or with surfaces quite so smooth as those on the die castings. Some of these shown are produced in cold chamber machines.



PART II—CONCLUDED FROM AUGUST

Die Castings Compared

by HERBERT CHASE

Porosity

Since die castings are made at high injection pressures, some air is usually trapped in the die casting. This produces pores or voids. Porosity is seldom if ever completely avoided although it can be confined, as a rule, to sections of the casting in which its effects are of little or no significance. Although porosity may not be completely avoided in permanent mold castings, it probably averages much less in degree than for the die casting, as the permanent mold casting is fed from a riser and with the metal flowing slowly upward so that the air in the cavities is likely to be displaced. A shrink "ball" or well at the top of the riser supplies metal until the casting is fully solidified. For such reasons, the permanent mold casting usually has an advantage as to soundness.

It is usually conceded that castings made at very high pressures in cold chamber die casting machines have less porosity than those made in air injection machines. It is doubtful, however, if any makers either of die castings or of permanent mold castings can safely guarantee complete freedom from porosity in all castings produced. Porosity in zinc alloy die castings and similar porosity as well as absorption of hydrogen in aluminum alloy die castings sometimes result in blistering if such castings be heated above a certain temperature, as in heat-treating or some finish baking operations. If the permanent mold casting has less porosity, this may make it preferable (when the comparison is confined to aluminum alloys) especially in those aluminum alloys which are rendered stronger by heat treatment.

Weight

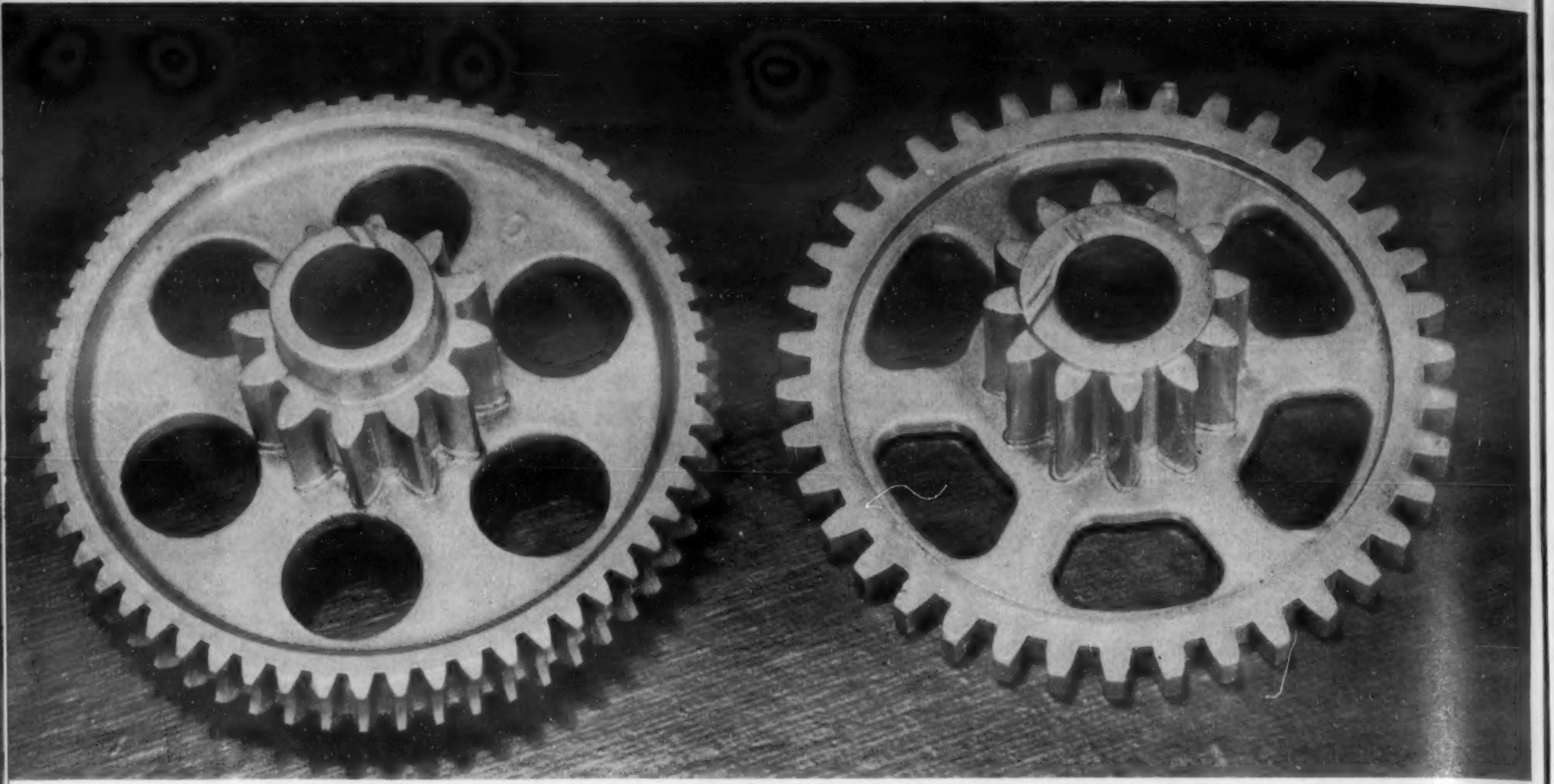
Because of the thinner sections which can be produced in the die castings, such castings frequently can be somewhat lighter than the permanent mold casting of the same alloy. Magnesium alloys are the lightest available for either type of casting and the art of making them is farther advanced in die casting than in permanent mold casting. It can thus be said that, of the two forms of castings, the die casting will be the lighter providing full advantage of weight reduction possibilities are taken in both instances.

Smoothness and Appearance

Assuming that the casting is to be used without an applied finish and without scratch brushing, polishing or the like, the permanent mold casting sometimes is preferred, as it comes from the mold with a relatively uniform frosted appearance and, in the case of some aluminum alloys, at least, with a lighter color than the corresponding die casting. This, among other items, has caused the permanent mold casting to be preferred for such parts as the grids for waffle irons. Another item in its favor is the lesser tendency for the waffle to stick to the grid which is an important consideration for such applications. Actually, however, the die casting is likely to be smoother than the permanent mold casting and, for this reason, may cost less to finish, especially if plating is required, as the smoother surface needs less polishing and buffing.

Dimensional Accuracy

That the die casting can be produced within closer dimensional limits than the permanent mold casting is seldom questioned. Some makers, at least, require plus or minus 0.010 in. minimum on all dimensions of small permanent mold castings, as against plus or minus 0.001 to 0.002 in. *per in.* for die castings, the latter applying to dimensions within solid parts of the die, not across parting lines or as between cores and fixed parts, where mechanical fits of die parts must be considered. A greater draft, 3 deg. is preferred (and required for deep draws) in the permanent mold and 1-½ deg. is the minimum for shallow draws for aluminum permanent mold castings. In some cases, this may be of no moment and in others it may necessitate more



These permanent mold gears, employed in a well-known make of domestic stoker, are cast from aluminum bronze and so close to size that the trim or shaving die, used for finishing the teeth is said to remove only 0.0005 to 0.0015 in. of metal.

machine work on the castings, but the advantage in this respect (as between alloys of the same base metal) favors the die casting, at least in a large proportion of cases.

Coring and Complexity

Much more complex castings and those with more and closer core work are feasible in die castings than in those made in permanent molds. The shape of the permanent mold casting (as here defined) must be such that it will fill out properly under the gravity head, whereas the use of high pressures, along with proper venting, assures the filling out of parts into which the metal would not otherwise flow in the die casting. This is not entirely a question of section thickness but involves such factors as gating and venting as well as that of applying enough pressure to produce the necessary flow before the metal freezes. Much more complex coring is done in the die casting and smaller cores are feasible, especially in using alloys of low melting point, than are considered feasible in most permanent mold work. On the other hand, the use of sand cores, as in semi-permanent mold castings, is not feasible in the die casting and permits of interior shapes not duplicated in the die casting.

Size of Castings

There are no very well defined limits as to size, either maximum or minimum, beyond which either type of casting cannot be made. In aluminum alloys, permanent mold castings up to 55 in. maximum dimensions have been made and fairly intricate castings up to 36 in. long are among those produced in considerable quantities. One maker of permanent mold castings in aluminum alloy indicates that castings up to 50 lbs. in weight are feasible and others down to about 1 oz. in weight can be made. Possibly even smaller castings would be feasible. The largest die casting in aluminum alloy yet made, to the author's knowledge, is a crankcase measuring 34 x 10 x 6 in. and weighing 17-½ lb. This involved a $6,000 die cost and a larger casting than many die casters would care to undertake. At least one die casting in magnesium alloy measuring 74 in. in length has been produced and many of similar length have been made in zinc alloy. Die castings weighing only a small fraction of an ounce are entirely feasible in zinc and in aluminum alloys and many such are produced in large quantities. The maximum in weight for zinc alloy die castings made to date is about 35 lb., but there is little doubt that this weight could be exceeded if demands for heavier castings were sufficient to justify die invest-

Table of Data on Permanent Mold and Die Casting Alloys

Typical Alloys				Approximate Chemical Composition (Per Cent)														Strength in Tension[4]			Strength in Compression[4]		Impact Strength	
A. S. T. M. Designation																								
Spec. No.	Alloy	S.A.E. Alloy No.	For Aluminum Alloys: Al. Co. of Amer. Alloy No. / For Zinc Alloys: N.J.Z. Co. Alloy No.	Copper	Silicon	Aluminum	Magnesium	Zinc[1]	Nickel	Cadmium	Lead	Tin	Iron	Condition	Approx. Sp. Gr. (Grams per cu. cm.)	Approx. Weight (Lbs. per cu. in.)	Relative Resistance to Salt Water[2] (A=Highest Rating)	Ultimate Tensile Strength (1,000 lbs. per sq. in.)	Yield Strength[3] (1,000 lbs. per sq. in.)	Elongation—% in 2 in. Rod Specimen (¼ in. dia.)	Yield Strength in Compres. (1,000 lbs. per sq. in.)	Shear Strength[5] (1,000 lbs. per sq. in.)	Charpy—Ft. Lb. ¼x¼ in. bar, 40 mm. span	Hardness, Brinnel No.
ZINC Die Casting Alloys:																								
B86-38T	XXIII	903	Zamak 3	0.1 max.	...	4.1	0.04	Rem.	..	0.005 max.	0.007 max.	0.005 max.	0.1 max.	As Cast	6.6	0.24	..	40	..[6]	5[7]	60[8]	31	20	80
B86-38T	XXI	921	Zamak 2	3.0	...	4.1	0.03	Rem.	..	0.005 max.	0.007 max.	0.005 max.	0.1 max.	As Cast	6.7	0.24	..	48	..[6]	5[7]	93[8]	46	20	90
B86-38T	XXV	925	Zamak 5	1.0	...	4.1	0.03	Rem.	..	0.005 max.	0.007 max.	0.002 max.	0.1 max.	As Cast	6.7	0.24	..	45	..[6]	3[7]	87[8]	38	20	85
COPPER Die Casting Alloys:																								
				65	1.0	..	...	34	..	....	....	....	..	As Cast	8.5	0.308	..	65	35	25	..	...	..	120
				81.5	4.0	..	...	14.5	..	....	....	....	..	As Cast	8.2	0.297	..	85	50	8	..	...	..	170
COPPER Permanent Mold Casting Alloys:																								
		68	McGill Metal	89	...	9	...	....	..	....	....	....	2	As Cast	7.5	0.27	..	75	35	15	..	...	25[9]	180
ALUMINUM Permanent Mold Casting Alloys:																								
B108-38T	9A	35	43	...	5.0	Rem.	...	...	..	....	....	....	..	As Cast	2.68	0.097	B	24	9	6.0	9	18.0	..	...
B108-38T	3	...	A108	4.5	5.5	Rem.	...	...	..	....	....	....	..	As Cast	2.77	0.100	D	28	16	2.0	16	25.0	..	...
....	....	33	112	7.5	...	Rem.	...	2.0	..	....	....	....	1.2	As Cast	...	0.104	D	27	19	1.5	19	23.0	..	...
....	....	...	B113	7.0	1.7	Rem.	...	...	..	....	....	....	1.2	As Cast	2.86	0.103	D	28	19	2.0	19	23.0	..	...
B108-38T	2	...	C113	7.0	4.0	Rem.	...	2.0	..	....	....	....	1.2	As Cast	2.86	0.103	D	30	24	1.0	24	22.0	..	...
....	....	34	122-T52	10.0	...	Rem.	0.2	...	..	....	....	....	1.2	H.T. & Aged	...	0.104	D	35	31	0.5	31	25.0	..	...
B108-38T	6	...	A132-T4	0.8	12.0	Rem.	1.0	...	2.5	....	....	....	0.8	H.T. & Aged	...	0.097	C	38	30	1.5	30	29.0	..	...
B108-38T	6	...	A132-T551	0.8	12.0	Rem.	1.0	...	2.5	....	....	....	0.8	H.T. & Aged	...	0.097	C	36	28	0.5	30	24.0	..	...
B108-38T	5	...	138	10.0	4.0	Rem.	0.2	...	..	....	....	....	1.4	As Cast	...	0.105	D	28	24	0.5	32	22.0	..	...
....	....	39	142	4.0	...	Rem.	1.5	...	2.0	....	....	....	..	As Cast	2.77	0.100	C	34	24	1.0	26	24.0	..	...
B108-38T	11	39	142-T61	4.0	...	Rem.	1.5	...	2.0	....	....	....	..	H.T. & Aged	...	0.100	C	47	42	0.5	46	31.0	..	...
B108-38T	11	39	142-T571	4.0	...	Rem.	1.5	...	2.0	....	....	....	..	H.T. & Aged	...	0.100	C	40	34	0.0	34	26.0	..	...
B108-38T	1	...	B195-T4	4.5	3.0	Rem.	...	...	..	....	....	....	..	H.T. & Aged	...	0.101	C	36	22	7.5	22	30.0	..	...
....	....	...	B195-T6	4.5	3.0	Rem.	...	...	..	....	....	....	..	H.T. & Aged	...	0.101	C	39	33	5.0	33	32.0	..	...
....	....	...	A214	...	...	Rem.	3.8	1.8	..	....	....	....	..	As Cast	2.68	0.096	B	27	16	5.0	17	22.0	..	...
....	....	322	355-T4	1.3	5.0	Rem.	0.5	...	..	....	....	....	..	H.T. & Aged	...	0.097	C	38	23	6.0	23	29.0	..	...
....	....	322	355-T6	1.3	5.0	Rem.	0.5	...	..	....	....	....	..	H.T. & Aged	...	0.097	C	43	26	4.0	26	30.0	..	...
ALUMINUM Die Casting Alloys:																								
B85-39T	V	305	13	...	12.0	Rem.	...	...	..	....	....	....	..	As Cast	2.66	0.096	B	33	18	1.8[7]	..	...	2.0	80
B85-39T	IV	304	43	...	5.0	Rem.	...	...	..	....	....	....	..	As Cast	2.68	0.097	B	29	13	3.5[7]	..	...	4.5	60
B85-39T	XII	312	81	7.0	3.0	Rem.	...	...	..	....	....	....	..	As Cast	2.85	0.103	D	32	24	1.3[7]	..	...	1.5	70
B85-39T	VI	...	83	2.0	3.0	Rem.	...	...	..	....	....	....	..	As Cast	2.75	0.099	C	30	14	3.5[7]	..	...	5.0	60
B85-39T	VII	307	85	4.0	5.0	Rem.	...	...	..	....	....	....	..	As Cast	2.78	0.101	C	35	19	2.7[7]	..	...	2.5	70
....	....	...	218	...	...	Rem.	8.0	...	..	....	....	....	..	As Cast	2.53	0.091	A	36	23	5.0[7]	..	...	..	...

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[1] In the case of zinc die casting alloys, only high purity (99.99+%) zinc may be used.

[2] An "A" rating is highest. Rating compares the stability of all aluminum-base alloys as a group, and is based on results of standard salt-spray tests. The ratings are as between aluminum alloys, among themselves, *not* as between aluminum alloys and those of other base metals.

[3] Yield strength is the stress at which the material exhibits a permanent set of 0.2 per cent.

[4] Mechanical properties are obtained on A.S.T.M. specimens. Since minimum guaranteed values vary with the commodity, these values are not given.

[5] Shearing strengths are single-shear values obtained from double-shear tests.

[6] The zinc alloys do not have a true yield strength.

[7] The elongation of the zinc and aluminum die casting alloys was determined on ¼-in. dia. bars.

[8] The compressive values for the zinc alloys are ultimate values. In these tests the specimens assumed a permanent compression of about 30 per cent.

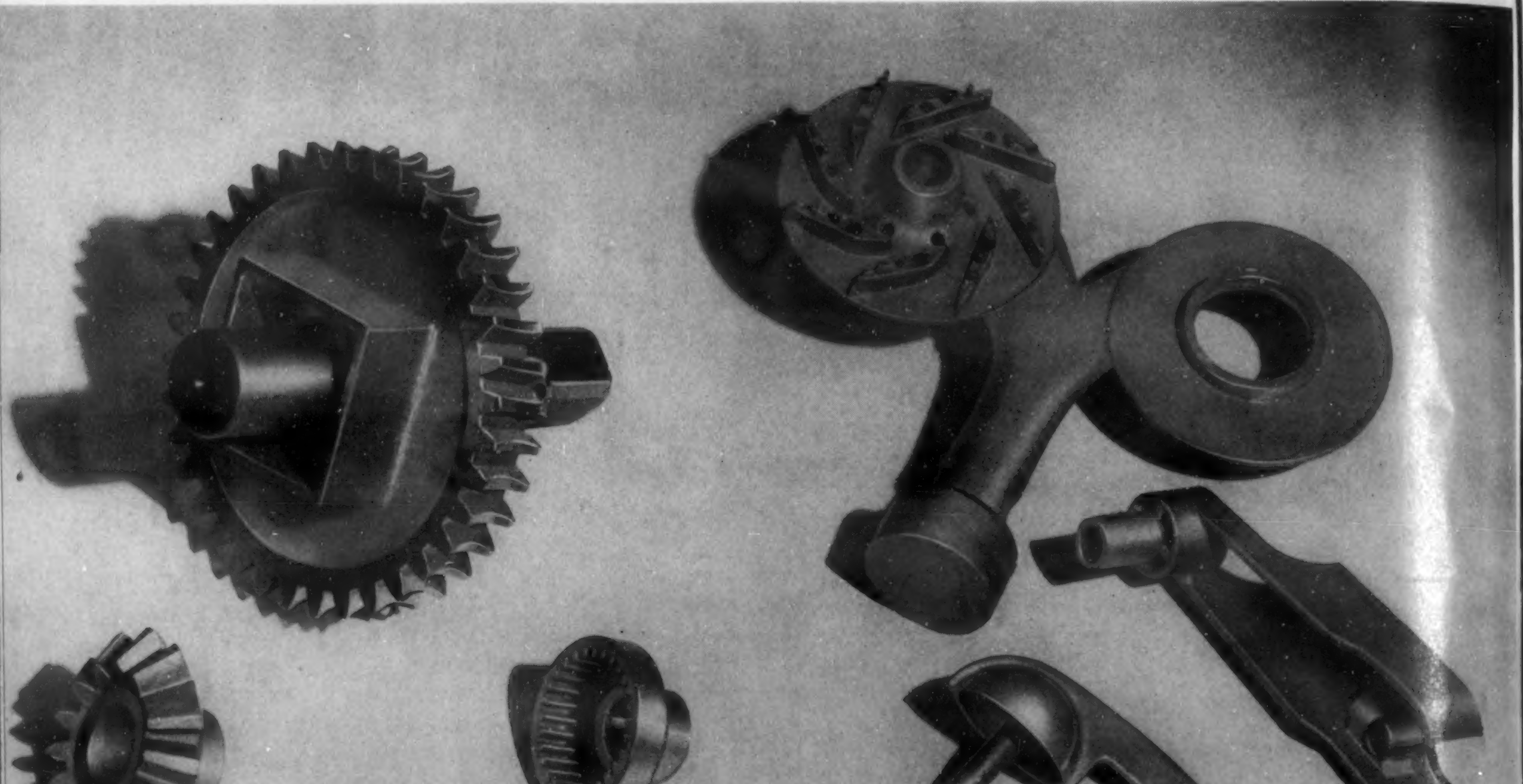
[9] Resistance to shear by impact, Izod, unnotched.

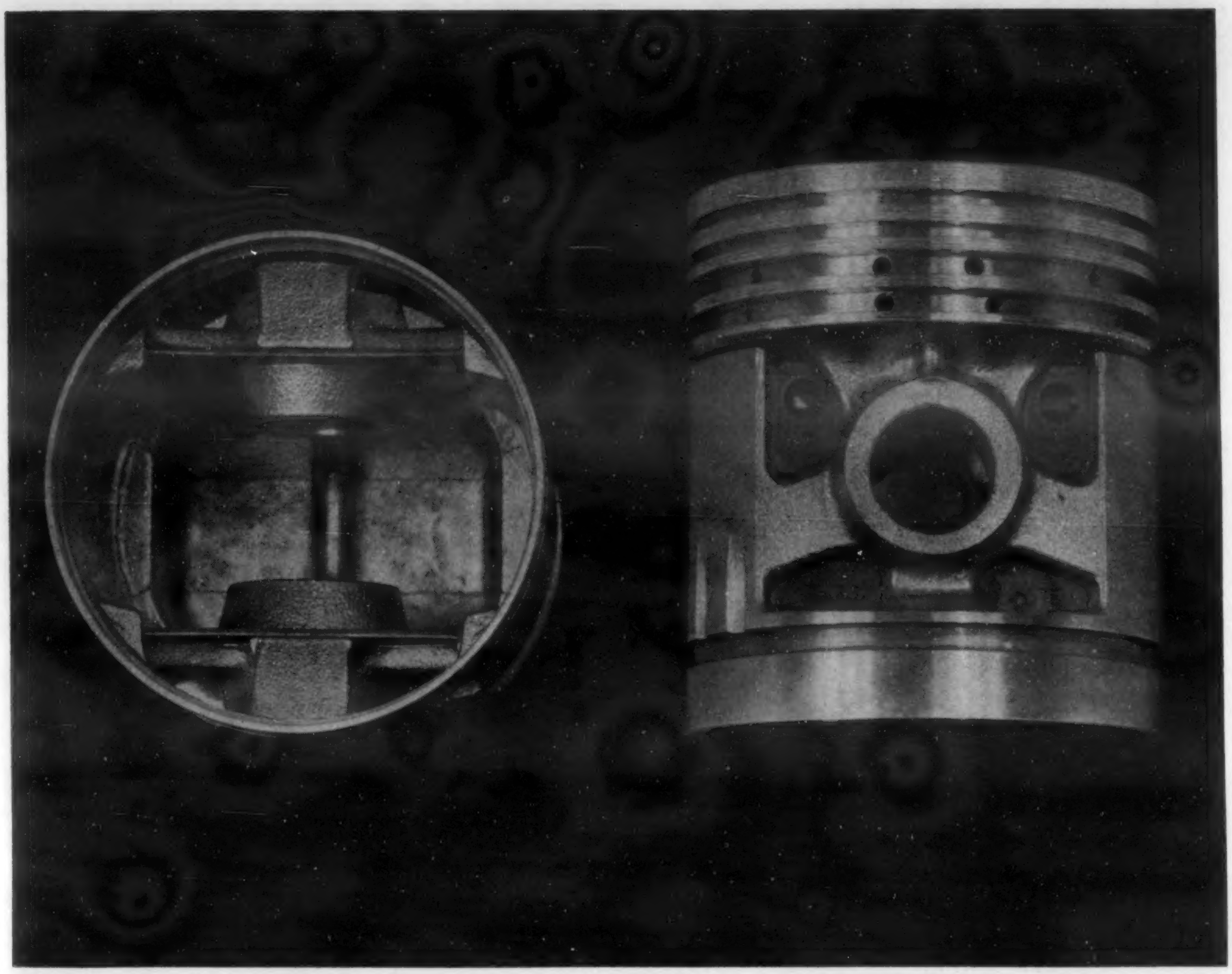
ments, which average lower than for dies to be used with alloys of higher melting point.

Relative Strength

General statements as to relative strength require so many qualifications that their value is somewhat doubtful. Some comparisons involving strength have been made above, however, and others, more specific, are given in the accompanying table. Tabular data naturally refer to standard test specimens the properties of which are not, of course, always duplicated in the castings themselves. Where strength is of paramount importance, the possible effects of porosity have to be considered and suitable factors of safety applied, as with other types of castings. Strength comparisons ought not to be based on tensile strength only unless strength in tension is a primary requirement, since impact strength and ductility are often of greater importance. The strength of certain aluminum alloys suitable for permanent

Two groups of copper-base castings all of which are produced by the McGill Mfg. Co. Those on the left are in "No. 1 McGill Metal," which is an aluminum bronze (see Table) and are made under gravity head in permanent molds. The group at the right are brass die castings produced under heavy hydraulic pressure. Some of each type have steel inserts and one pair of die castings is shown with the gate or sprue, including the slug of excess metal, still attached.





Permanent mold aluminum piston, typical of those produced in vast quantities for many internal combustion engines. Because the core has to be undercut to form the recesses below the bosses, it is made in three sections which are removed separately from the casting.

mold castings can be greatly improved by heat treatment as already indicated, but the cost of such treatment should not be overlooked if minimum cost is desired. On the other hand, it is feasible to heat treat permanent mold castings where similar treatment of die castings is usually ruled out because it is likely to result in blistering. In general, strength is only one of several factors to be weighed in arriving at a choice which combines the greatest number of advantages with a minimum number of disadvantages.

Conclusions

In a brief article such as this it is not feasible, of course, to go into details concerning specific cases, but the foregoing outline of considerations having a bearing on a choice between die castings and permanent mold castings points out some of the major considerations involved. When the engineer is faced with a choice between one or the other of the types of castings dealt with here and some definite consideration does not bar either form, he may well make designs for both types and secure comparative estimates. Before doing so, however, he may profitably submit tentative designs to reliable makers of each type of casting, for constructive criticism. By so doing he can make sure that the designs in their finished forms make the most of economies inherent in each type. Otherwise, he may unwittingly specify types of construction or limits so close that costs are materially higher than they need be.

Accompanying illustrations give some idea as to types of parts produced in die cast and permanent mold forms and captions indicate certain factors influencing the choice. In the table are given data furnished by makers of castings of each type or by those who supply the alloys and/or the base metals which are employed. Certain other alloys not listed are sometimes used, but those listed are generally regarded as best suited for the purposes indicated.

Substitute Solders

In the selection of substitute materials it is necessary to be careful not to run from one bottle-neck into another. Hence the comments on the suitability of Pb-Sn-Cd solders should be read with the recollection that the supply of cadmium is so limited that any extensive use in solder would create a troublesome scarcity.—H. W. G.

by F. N. RHINES and W. A. ANDERSON

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SOMEWHAT IN EXCESS OF ONE FIFTH of the tin consumed in the United States goes into the manufacture of solders; no one type of application, with the single exception of tin plate, uses more than one third this amount. With the growing possibility of curtailment in tin supplies to the United States, it is appropriate that an effort be made to find satisfactory substitutes in an application such as this which is vital both to peace-time industry and to the manufacture of war materials.

In the First World War

During the first World War much work was done in Europe and some in the United States in an attempt to reduce the percentage of tin in solders. No generally applicable tin-free soft solder was developed but tin-poor solders were developed to the point where the German Government felt justified in prohibiting the use of more than 15 percent Sn in any solder; this represented a saving of about two thirds of the tin normally allotted to this use. Because of their inferior quality, few of the substitute solders survived through the peace years; there has been little recent advance in this field and much of what was known previously has been forgotten.

Before entering upon an extensive search for new substitute solders, it will be advantageous, therefore, to examine carefully what was done in this field during the former emergency, in order that new studies may be begun where work was discontinued in 1919. It is the purpose of the present paper to present a tabulation of the principal solder combinations that have been proposed together with a comparison of the properties of these solders made upon a uniform basis. This should serve the purpose of providing a list of tested compositions from which substitutes for immediate use may be drawn and should forestall needless duplication of research effort in any further quest for better substitutes.

The literature has been searched to obtain a list of 75 alloys which are representative of virtually all of the types of compositions that have been proposed as soft solders excepting those intended only for the joining of aluminum. Since the claims made for special properties in these alloys are necessarily based upon a wide variety of tests, it has been found advisable to re-examine this entire group with a series of standardized tests. The results of this work are recorded in the Table.

The tin-lead alloys are remarkable in the latitude of their usefulness. They may be employed for the joining of a majority of the common metals, ranging all the way from the relatively high-melting metals of the copper group down to low-melting metals such as tin, lead, zinc, and their alloys. Moreover, the tin-lead alloys can be handled by relatively simple techniques; they are not subject to rapid oxidation when molten or to severe corrosion in use; and they produce the strongest joints of all of the known low-melting alloys. Although these solders have been in use continuously for thousands of years, no generally useful competitive alloys have appeared. It is too much to expect, therefore, that any one alloy will be found suitable for all of the applications to which tin solders are normally put. At best, it may be hoped that a number of tin-poor or tin-free alloys may be found which will collectively cover the main range of usefulness of the tin-rich solders.

Possible Substitutes Classified

For this reason the search for substitute solders may well be divided into several classifications, such as materials suitable for joining.

1. Copper and its alloys.
2. Galvanized iron.
3. Tin plate.
4. Lead and pewter.
5. Aluminum and its alloys.

Of these classes copper and its alloys present by far the most difficult soldering problem, partly because of the limited number of alloys that will properly wet copper, and partly because of the exacting requirements involved in the fabrication of copper and brass articles. Zinc and tin-coated materials and the white metals present a much less difficult soldering problem, because most of these can be joined either with lead-rich or zinc-rich alloys; and there are a great many of these available. Little soldering of aluminum is practiced; tin-free alloys are currently in use for this purpose. The tests here reported have been confined, therefore, to the most pressing problem—the joining of copper; it is assumed that solders suitable for joining copper will also be suitable for joining the majority of the copper alloys, but some exceptions will be found.

Choice of a Flux

It has been necessary to eliminate another variable, namely, the choice of flux. A flux composed of zinc chloride, with or without ammonium chloride additions, has been found to be generally useful in handling all soft solders. In certain industrial applications it is impractical to use this type of flux because of its chemical reactivity; rosin is commonly used as a substitute. Since the zinc chloride-ammonium chloride flux is most widely useful, however, it has been selected as a standard in making the present group of tests. The composition employed was 65 percent $ZnCl_2$ and 35 percent NH_4Cl dissolved in water.

Experimental Procedure

The alloys listed in the Table were all made from pure metals melted together in clay-graphite crucibles in a gas furnace. Charcoal was employed as a cover. One pound of each alloy was prepared in a single heat. Since significant deviations from the nominal compositions are not to be expected among alloys of this class, no chemical analyses have been made. There was evidence of loss by oxidation only among the alloys containing cadmium and zinc; it is believed that these losses were not significant. After thorough stirring the molten metal was cast as conveniently shaped bars in a horizontal iron mold.

The following physical tests were made:

1. Tensile strength of a soldered joint between copper bars.
2. Shear strength of a soldered joint between copper bars.
3. Capillary rise of solder between parallel copper bars.
4. The spread of a drop of solder on a horizontal copper surface under flux.
5. The rate of corrosion of the solder itself in a standard salt spray test.

The purpose of the tensile and shear tests is self evident. Strengths of the solders themselves are often reported in the literature, but it is felt that the strength of a soldered joint, which may bear little relation to the strength of the solder itself, will be of greater practical significance in the present case. The capillary rise of solders is a property of increasing importance with the growing use of soldering techniques that depend upon capillary flow to fill the joint. An indication of the "wetting" ability of the solder is given by the "spread of a drop" test. Corrosion resistance is a property that cannot be satisfactorily determined without reference to the specific environmental conditions in which the material is to be used, but those alloys of marked inferiority will generally be identified by a standard salt spray test.

In order to standardize the soldering procedure, all joints were made at a temperature 60 deg. C. above the liquidus temperature of the solder. Capillary rise and "spread of a drop" tests were also made at this temperature. For the most part, the melting temperatures (liquidus and solidus) of the alloys were obtained from the literature. Where such data were not available, they were determined directly with the solder used in the tests. Liquidus temperatures were determined in the usual way, by means of cooling curves. Solidus temperatures, when they could not be read accurately from the cooling curves, were determined by the Hanson technique, that is, by measuring the temperature at which a loaded bar of the solder suddenly ruptures upon slow heating. Some idea of the maximum useful temperature range of the solder can be obtained from the solidus temperature.

Tensile Strength

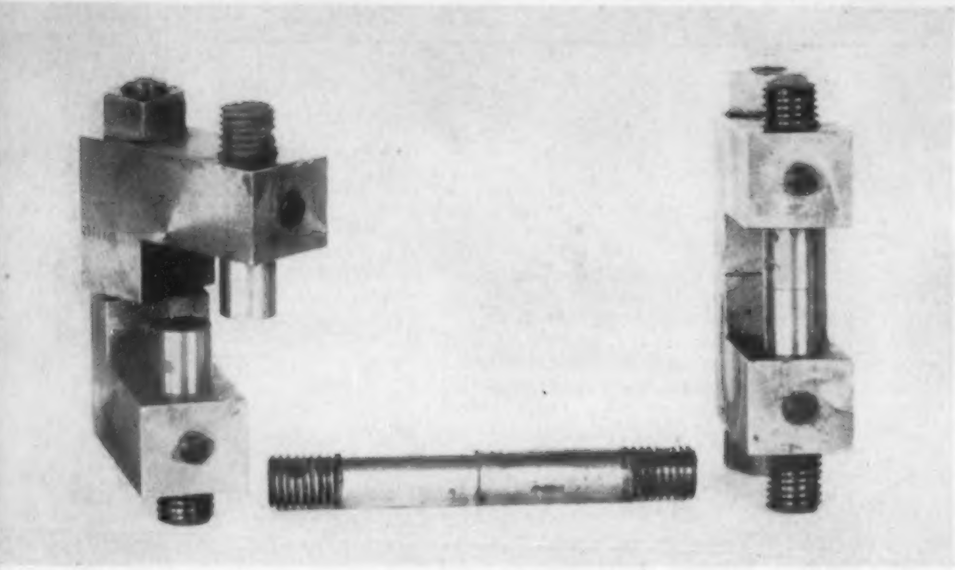
The tensile strength of a soldered joint is very critically dependent upon the thickness of the solder layer. To a less marked extent the time of heating will also influence the strength of the joint. In general, there is an optimum thickness of joint somewhere in the neighborhood of 0.005 in., where the best tensile strengths are reached; beyond this thickness, the strength drops off rapidly. Lower tensile strengths found in joints thinner than about 0.003 in. are quite possibly the result of difficulties involved in producing perfect joints. Increased times of heating increase the thickness of the intermetallic com-

Table of Comparison of the

Alloy No.	Composition in Weight Per Cent							Liquidus temperature, Deg. C.	Solidus temperature, Deg. C.	Soldering temperatures used in tests, Deg. C.	Tensile strength copper joint 0.005 in. thick in lbs. per sq. in.	Shear strength copper joint 0.005 in. thick in lbs. per sq. in.	Capillary rise in inches between ¼ in. copper rods 0.007 in. apart	Spread of a drop 0.1 c.c. in volume on copper. Expressed in sq. in., Covered
	Sn	Pb	Sb	Cd	Bi	Zn	Others							
1	100	....	....	....	....	....	....	231.9	231.9	292	22,706	6,880	1.25	0.35
2	....	100	....	....	....	....	....	327.35	327.35	387	0	0	0.56	0.26
3	25	75	....	....	....	....	....	266	183	326	13,500	5,795	0.62	0.81
4	15	85	....	....	....	....	....	285	225	345	13,300	5,640	0.50	1.17
5	5	95	....	....	....	....	....	313	291	373	10,700	6,380	0.44	0.34
6	63	37	....	....	....	....	....	183	183	243	29,000	8,000	1.19	0.97
7	50	50	....	....	....	....	....	216	183	276	23,900	7,580	0.94	1.5
8	45	55	....	....	....	....	....	225	183	285	28,800	8,060	1.12	2.79
9	40	60	....	....	....	....	....	238	183	298	14,100	8,280	0.94	1.76
10	37.5	62.5	....	....	....	....	....	239	183	299	23,700	8,460	1.06	1.69
11	33	67	....	....	....	....	....	252	183	312	17,100	6,450	1.00	1.61
12	49.25	50	0.75	....	....	....	....	208	185	268	16,300	8,760	1.00	1.49
13	43.5	55	1.5	....	....	....	....	220	188	280	17,550	7,720	1.00	1.77
14	38	60	2	....	....	....	....	228	188	288	20,100	7,714	0.56	1.24
15	35.5	62.5	2	....	....	....	....	231	188	291	15,100	7,600	0.94	0.93
16	31	67	2	....	....	....	....	235	188	295	15,300	7,260	0.94	0.99
17	37.5	60	2.5	....	....	....	....	224	186	284	17,350	8,250	1.00	2.03
18	4	90	6	....	....	....	....	276	239	336	8,500	6,640	0.06	0.19
19	66	27.5	....	6.5	....	....	....	172 *	137 *	242	17,240	9,940	1.12	1.00
20	65	13.5	....	21.5	....	....	....	160 *	137 *	220	13,000	10,020	0.81	0.88
21	50	25	....	25	....	....	....	160	145	220	14,600	9,520	0.75	1.18
22	50	32	....	18	....	....	....	145.5	145.5	205	14,900	9,600	0.69	1.14
23	32.5	39.5	....	19	....	2	....	165	136	225	18,600	9,950	1.06	0.93
24	23	68	....	9	....	....	....	235	145	295	16,600	7,900	0.75	1.24
25	15	75	....	10	....	....	....	245	145	305	13,710	4,760	0.56	1.09
26	10	80	....	10	....	....	....	253	145	313	13,660	6,440	0.62	0.91
27	10	85	....	5	....	....	....	260	145	320	11,720	4,770	0.62	0.73
28	10	88	....	2	....	....	....	275	145	335	16,780	5,150	0.75	0.65
29	9	65	....	26	....	....	....	225	145	285	14,630	6,980	0.69	0.86
30	5	85	....	10	....	....	....	257	145	317	11,870	4,770	0.81	0.74
31	3	75	....	22	....	....	....	237	145	297	12,910	6,050	0.81	0.94
32	2	86	....	12	....	....	....	262 *	239 *	322	13,880	6,100	0.44	0.69
33	50	25	....	....	25	....	....	130 *	110 *	190	9,140	6,140	0.62	0.71
34	45	27.5	....	....	27.5	....	....	94	....	154	10,760	4,880	0.38	0.66
35	22	28	....	....	50	....	....	100	....	160	11,150	7,360	0.38	0.61
36	20	40	....	....	40	....	....	113	....	173	12,700	6,530	0.75	0.60
37	19	31	....	....	50	....	....	94	....	154	5,790	6,510	0.69	0.41
38	13	27	....	10	50	....	....	70	....	130	12,120	6,580	0.38	0.32
39	37.5	....	....	12.5	50	....	....	66	....	126	9,000	7,040	0.44	0.30
40	33.3	....	....	16.7	50	....	....	66	....	126	10,930	9,440	0.62	0.42
41	25	....	....	25	50	....	....	66	....	126	8,520	8,250	0.50	0.47
42	....	53.8	....	15.4	30.8	....	....	80	....	140	9,820	5,840	0.31	0.22
43	....	42.7	....	7.1	50	....	....	88	....	148	11,940	5,540	0.18	0.13
44	....	42	....	15.7	42.3	....	....	89.5	....	150	10,300	5,600	0.18	0.17
45	30	....	....	50	....	20	....	277 *	157 *	337	12,370	8,920	1.00	0.36
46	15	....	....	20	....	65	....	346 *	157 *	406	11,300	10,480	2.00	0.84
47	5	....	....	65	....	30	....	294 *	229 *	354	15,850	9,870	1.25	0.75
48	....	91.5	....	8.5	....	....	....	276	249	336	13,150	6,980	0.62	0.25
49	....	90	....	10	....	....	....	274	249	334	13,940	7,100	0.56	0.32
50	....	80	....	20	....	....	....	259	249	319	13,400	8,140	0.69	0.60
51	....	70	....	30	....	....	....	260	249	320	14,000	6,510	0.50	0.36
52	....	90	10	....	....	....	....	266	247	326	3,490	3,140	0.06	0.14
53	....	87	13	....	....	....	....	247	247	307	2,365	5,770	0.06	0.11
54	....	....	....	82.6	....	17.4	....	264.4	264.4	324	13,340	11,250	0.88	0.53
55	....	....	....	50	....	50	....	326	264.4	386	12,600	10,410	1.69	...
56	....	....	....	40	....	60	....	335	264.4	395	6,680	12,050	1.94	1.03
57	....	....	....	25	....	75	....	364	264.4	424	9,130	8,580	1.56	0.66
58	....	90.8	....	7.8	....	1.4	....	267	237	327	16,400	7,410	0.62	0.35
59	....	87.5	....	7.5	....	5	....	368	235	428	10,920	5,820	0.94	0.41
60	6	86	....	....	....	....	8 Hg	282 *	247 *	342	13,450	5,770	0.62	0.32
61	3	93	....	....	....	....	4 Hg	384 *	270 *	364	11,160	5,330	0.31	0.36
62	50	....	25	25	....	....	....	311 *	214 *	371	5,110	9,030	0.94	...
63	50	25	....	....	....	25	....	336 *	155 *	396	15,960	10,030	1.31	0.39
64	37.3	62.7	....	....	....	....	.1 As	240	183	300	16,550	7,910	1.12	1.79
65	95	....	5	..	....	....	....	240	232	300	14,200	11,080	0.88	0.29
66	41.5	56.5	2	....	....	....	.02 P	220	....	280	10,300	10,000	1.00	0.79
67	....	79.7	2.6	17.7	....	....	....	239 *	....	299	14,600	7,130	0.06	0.13
68	....	95	....	....	....	5	....	418	318	478	9,460	4,770	0.94	...
69	....	97	....	....	....	....	0.25 Cu; 2.5 Ag	350	300	410	11,500	4,770	0.75	0.41
70	....	....	....	95	....	....	5 Ag	390	337	450	9,510	10,650	0.75	1.91
71	....	....	....	....	....	98	2 Ni	550	419	500	9,450	.....	0.88	0.31
72	....	98	....	....	....	....	2 Ag	308	304	364	9,560	4,420	0.50	0.35
73	....	95	....	....	....	....	5 Ag	365	304	425	9,100	4,100	0.62	0.41
74	....	98	....	....	....	....	2 Tl	310	308	390	8,600	5,890	0.69	0.20
75	95	....	....	....	....	....	5 Ag	295	221	305	14,100	10,610	1.00	0.91

* Temperatures measured in this investigation.

Spread of a drop 0.1 c.c. in volume on copper. Expressed in maximum thickness of film in inches	Appearance of Cast Surface	"Tinning" qualities with reference to copper	Corrosion in 3% NaCl spray. Per cent loss in weight after 98 days	Corrosion in 3% NaCl spray. Per cent loss in weight after 203 days	Recommended uses	References to Bibliography
0.0279	Bright, furrowed	Very good	0.220	0.442	Electrical equipment	17
0.0376	Dull	Very poor	0.120	0.247	None	21
0.0139	Frosty	Good	0.156	0.326	General low grade; filler	12
0.0102	Dull, very frosty, traces of a furrow	Fair	0.190	0.389	General low grade; coating, jointing; high temp. uses	22, 31, 41
0.0275	Bright, slight frostiness, slight furrow	Fair	0.097	0.260	"	12, 27
0.0164	Bright, slightly discolored	Good	0.325	0.708	Fine solder, General purpose.	13, 15, 26, 36, 45
0.0060	Bright, traces of a furrow	Good	0.292	0.618	General purpose	9, 13, 15, 16, 26, 36, 45, 46
0.0055	Bright, slightly frosty in places	Good	0.288	0.678	Radiators, roofing	13, 15, 26
0.0070	Frosty, slightly discolored	Good	0.248	0.515	Wiping, radiators	13, 15, 46
0.0076	Very frosty	Good	0.260	0.525	Wiping, radiators	13, 14, 15
0.0119	Very frosty	Good	0.342	0.697	Wiping	13, 15, 26, 45
0.0096	Bright, slightly discolored	Good	0.455	0.765	General; tin plate	10, 13, 15
0.0075	Frosty, furrowed, slightly drossy	Good	0.429	0.930	General purpose	10, 13, 15
0.0093	Very frosty, slightly discolored	Good	0.457	0.709	Wiping	10, 13, 15
0.0155	Very frosty, slightly discolored	Good	0.292	0.756	Wiping	10, 13, 15
0.0135	Frosty, spotted, slightly drossy	Fair	0.314	0.629	Wiping	10, 13, 15
0.0055	Frosty and bright, spotted	Fair	0.272	0.688	Wiping	10, 12, 15
0.0534	Very frosty, furrowed	Poor	0.230	0.406	High temperature service	15, 41
0.0145	Dull, frosty, slightly furrowed	Fair	0.097	0.410	Wiping	19, 39
0.0162	White, frosty	Fair	0.162	0.950	Wiping	19, 39
0.0180	Bright, roughened trace of shallow furrow	Fair	0.153	1.175	General purpose	19, 46
0.0187	Bright, smooth	Good	0.040	0.594	Fusible safety devices	6, 39, 46
0.0170	Dull, frosty, spotted	Good	0.192	1.172	General purpose	9
0.0103	Dull, frosty, grainy	Good	0.017	0.443	Wiping	14, 39
0.0094	Slightly frosty	Fair	0.046	0.380	Coating and jointing	20, 39
0.0135	Dull, frosty	Fair	0.019	0.405	Gen.; elect.; cans; roofing	2, 5, 9, 19, 20, 25
0.0120	Dull, rough	Fair	0.214	0.494	General purpose	41
0.0200	Dull, frosty, furrowed	Fair	0.143	0.451	General purpose	41
0.0121	Bright, frosty, furrowed	Fair	0.150	0.684	General purpose	39
0.0141	Dull, frosty, trace of furrow	Fair	0.083	0.551	General purpose	19, 20
0.0114	Bright, rough furrow	Fair	0.236	0.743	General purpose	39
0.0197	Very dull and frosty, shallow furrow	Fair	0.250	0.787	General purpose	18
0.0170	Dull discolored, appears "etched"	Fair	0.151	0.289	Joining pewter	23, 26
0.0190	Bright, frosty, appears "etched"	Fair	0.223	0.473	Pewter, lead, tin, Britannia.	23, 32
0.0290	Bright, slightly frosty, furrowed	Fair	0.216	0.340	Lead, tin, Britannia	23
0.0176	Very dull deep frost, trace of furrow	Fair	0.206	0.431	Lead, tin, Britannia	23, 32
0.0250	Bright, slightly frosty, "etched," slight furrow	Fair	0.207	0.331	Britannia	12, 23
0.0315	Dull, frosty, slight furrow	Fair	0.334	1.048	Fusibility, glass-metal	12, 23, 44
0.0265	Dull, frosty, furrowed, appears "etched"	Fair	0.198	0.620	Fusible alloy	19
0.0230	Frosty, slight furrow, appears "etched"	Fair	0.342	1.371	Fusible alloy	19
0.0221	Frosty with bright facets	Fair	0.196	1.580	Fusible alloy	19
0.0459	Frosty with bright facets	Fair	0.405	1.347	Fusible alloy	19
0.0785	Dull deep frost	Fair	0.441	0.314	Fusible alloy	19
0.0520	Slightly frosty, showing facets	Fair	0.343	1.367	Fusible alloy	19
0.0095	Dull, frosty, showing facets	Fair to poor	1.685	3.990	....	19
0.0195	Dull white, frosty, appears "etched"	Fair to poor	2.190	4.810	....	29
0.0155	Frosty, acicular ridges	Fair to poor	1.130	3.740	....	19
0.0140	Dull brown oxide over all	Fair	....	0.198	Carbon, Copper, Zinc, Iron.	11, 19, 28
0.0350	Deep brown oxide over all	Fair	0.0215	0.509	Copper, zinc, iron	4, 17, 19, 25
0.0180	Bright, frosty, rough irregular surface	Fair	0.134	0.845	....	17, 19
0.0322	Dark blue-brown oxide over all	Fair	....	0.340	....	19
0.0770	Bright, frosty	Very poor	0.128	0.368	Lead cable	38
0.0945	Bright, frosty	Very poor	0.244	0.425	Lead cable	38
0.0195	Bright, shiny	Poor	0.279	1.022	High temp.; galvanized	8, 12, 30, 33, 37
.....	Bright, frosty, rough	Poor	1.870	3.820	High temp. service	12
0.0155	White, frosty	Poor	2.230	4.470	Bronze; Al to Cu	19, 34
0.0201	Dull white, frosty	Poor	1.480	6.040	High temp. service	18
0.0279	Dull, frosty, spotted	Fair	0.0541	0.460	Copper, iron, tin, galv	5, 19, 25, 46
0.0261	Bright, shiny, rough	Fair	0.519	1.028	Copper, iron, tin, galv	3, 19, 46
0.0327	Bright, frosty	Fair	0.314	0.589	Galvanized, sheet iron	38
0.0275	Dull, appears "etched," coarse furrow	Fair	0.195	0.379	Galvanized, sheet iron	7, 38
.....	Bright, discolored, acicular ridges	Fair	0.106	0.476	Pewter, Britannia, Sb-lead	19
0.0370	Dull, frosty, coarse	Fair to poor	1.280	2.740	Aluminum	1
0.0065	White, frosty, spotted	Good	0.478	0.903	Wiping	40
0.0340	Bright, shiny, appears "etched," trace of furrow	Good	0.275	0.415	Electrical equipment	12, 17
0.0173	Bright, shiny, spotted	Good	....	....	General purpose	24
0.0680	Very dull, frosty, rough	Fair	0.087	0.590	....	....
.....	Bright, frosty, coarse	Poor	0.131	0.848	High temp. service	3
0.0361	Bright, spotted	Poor	0.138	0.513	Electrical equipment	42, 43
0.0400	Dull brown oxide over all	Fair	0.893	3.840	High temp. service	12
0.0440	Bright, frosty, rough, furrowed	Poor	2.240	10.210	Carbon; high temp	3, 11
0.0280	Dull, rough, coarse furrow	Fair	....	....	Electrical; high temp	17, 27, 43
0.0269	Dull, discolored, rough	Fair	0.098	0.379	Electrical; high temp	17
0.0485	Bright, shiny, trace of furrow	Poor	....	....	Electrical; high temp	27
0.0140	Bright, shiny	Good	....	....	Electrical; high temp	17



Jig for producing tensile and torsion test joints. At left, jig open for tinning; at right, closed to complete joint; at center, finished test bar.

pound layers in the solder and frequently result in a decrease in the tensile strength. Thus the best conditions for testing seem to be: A joint thickness of 0.005 in. made with the shortest possible time at the soldering temperature.

Test bars made by joining two copper rods each ¾ in. in diameter and machined flat on the abutting ends were produced in a special jig which held the ends of the bars exactly the pre-determined distance apart. In soldering the assembly was heated in a thermostatically controlled, pit-type, electric furnace until a temperature of 60 deg. C. above the melting point of the solder was attained. Flux was then applied to the ends of the test bars and solder immediately flowed on. During this operation the two parts of the test bars were hinged apart, in order to provide easy access and to insure perfect tinning. As soon as the solder had been applied the ends of the bars were brought together in a wiping motion designed to push out all air bubbles, oxide, and remnants of flux. Perfectly clean joints were consistently obtained in this way. This method was found to be far superior to the more usual technique of allowing the solder to rise between fixed surfaces. Immediately after soldering, the jig assembly was removed from the furnace and was allowed to cool until the solder was frozen, whereupon cold water was applied to reduce the temperature as quickly as possible.

A minimum of 5 joints of each alloy, made in this way, were loaded to rupture in a tensile machine. The average ultimate strengths so measured are reported in the Table. Some deviation in the strengths from bar to bar is inevitable in tests of this sort; for the most part, the deviation was not greater than ± 10 per cent of the reported ultimate strength, usually much less. It is noteworthy that the alloys showing the greatest tensile strengths generally break *through* the solder, whereas those showing relatively low tensile strengths frequently break *between* the solder and the copper.

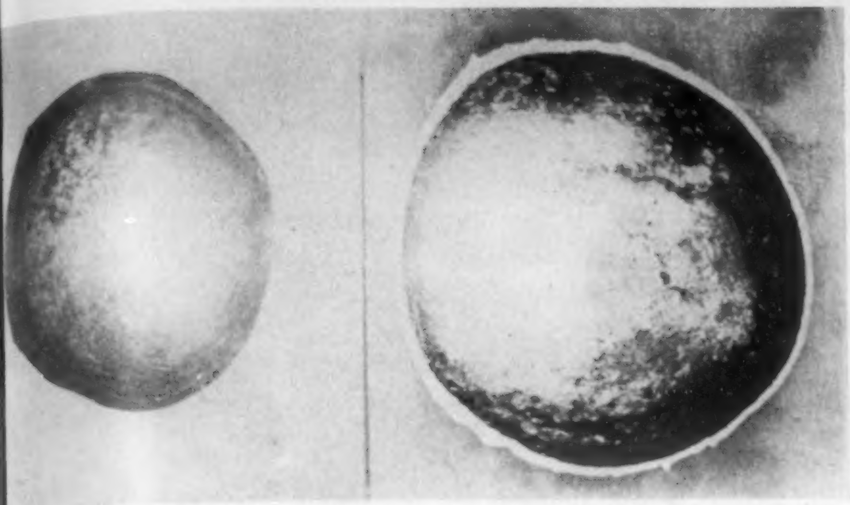
Shear Strength and Capillary Rise

Test bars similarly prepared were employed in the shear tests and were broken in a standard torsion testing machine. The results are again listed in the Table. It will be observed that there is little correlation between the tensile and shear strength among many of the alloys; presumably, a difference in the mechanism of failure is responsible for this divergence. This observation indicates the importance of choosing a solder for the particular service to which it is to be subjected.

For the capillary tests pairs of copper rods, each ¼ in. in diameter, were clamped together with strands of cupro-nickel wire, 0.007 in. in diameter placed between them at the ends. The protruding ends of these wires were bound around the assembly to hold the rods tightly against the spacer strand. By using carefully straightened rods and limiting the length to 3 in., adequate precision was obtained in the control of the dimensions of the capillary space. The rod assembly was preheated to 60 deg. above the melting point of the solder, which at the same time was brought to temperature in an electric furnace. Flux was applied to both the copper rods and the solder bath, and the assembly was immediately lowered a pre-determined distance into the solder. Fifteen seconds were allowed for the solder to rise in the capillary space, after which the assembly was removed from the furnace and cooled. The maximum travel of the solder, readily detected by the traces of solder left between the bars, was measured with a ruler. The height of rise for each alloy is recorded in the Table.

Spread of a Drop

As a qualitative test of the behavior of the solder under working conditions, the extent of the spread of a bead of solder was observed. This was done by placing upon flat, level plates of copper, fluxed and held at a temperature 60 deg. C. above the melting point of the solder, samples of solder exactly 0.1 c.c. in volume. During a period of 15 sec. the solder was allowed to spread, whereupon the plates were removed from the furnace and were cooled as rapidly as possible with a blast of air on the under side. Some alloys spread very rapidly in this test, while others form a bead that spreads very little. Those that spread rapidly are seen to advance with a band of apparently solid alloy proceeding ahead of the main body of liquid. In such cases the area covered may be quite irregular. Two measurements have been recorded in the Table: (1) the area covered by the drop and (2) the maximum thickness of solder on the plate. Large areas and small film



"Spread of a drop" test showing manner in which the solder spreads with a margin of solid alloy growing ahead of the spreading molten mass. Tin-lead solder (50-50) on copper using a resin flux (left) and a zinc chloride-ammonium chloride flux (right). Mag. about 3X.

thicknesses will generally correspond to an easily worked solder, that is, one that will wet copper readily.

Corrosion

While it might seem most useful to test the corrosion resistance of soldered joints rather than that of the solder itself, it did not appear advisable to attempt to standardize such a test within the short period of time available for the work. Instead, bars of the solder have been subjected to the action of a 3 per cent NaCl mist, in a standard salt-spray tank, for periods up to 6 mos. At the end of 3 mos., the bars were removed from the testing chamber, scrubbed and weighed. The percentage loss in weight for each alloy is listed in the Table. After examination the bars were returned to the testing tank for another 3 mos., when the examination was repeated. The samples, although not exactly uniform in size, were approximately $2\frac{1}{2}$ sq. in. in surface area.

Surface Appearance and Ease of Tinning

In addition to the physical tests, several qualitative observations of some interest to the user of solder have been recorded in the Table. The appearance of the cast surface of the solder observed on the original cast bars is described with a series of self-explanatory terms. While the surface appearance of solders is generally of more aesthetic than engineering importance, it does occasionally appear as a rather important factor in limiting the applicability of the solder; for example, those alloys that oxidize readily may be undesirable in the joining of electrical parts or for use in automatic soldering machines.

A more or less definite indication of the tinning qualities of the solder has been given by the spread of a drop test. Some indeterminate factors sometimes appear to come into play in influencing the general ease of handling a solder, however, and a series of comments on this point may be useful. Under the heading, "Tinning Qualities," have been listed a technician's impressions of the working qualities of each alloy. Those marked "poor" can be caused to wet the copper only by excessive rubbing, whereas those marked "good" can be tinned by simply flowing the solder onto the copper.

Uses

Although the present investigation has been purposely limited to the soldering of copper, it will be understood that many of the alloys tested are to be recommended for other purposes. In the Table under the heading, Recommended Uses, are listed the applications of each alloy claimed in the literature. The truth of these claims with respect to metals other than copper has not been examined in the present investigation. For the convenience of the reader who may wish to obtain more specific information about any particular alloy, an abridged bibliography has been assembled, and a classified list of the references is given in the last column of the Table.

Discussion

Among the alloys that have been tested is an extensive series of binary tin-lead compositions. This has been included in order to provide a basis for comparing the properties of substitute solders with the commonly used tin-rich compositions. In making the comparison it will be convenient to consider first those alloys in which the tin content is simply reduced and second those alloys from which tin has been entirely eliminated. Among the alloying elements that have been used as partial substitutes for tin are antimony, cadmium, bismuth, zinc, and mercury.

Antimony: The lead-tin-antimony alloys have been extensively exploited, and it has been found through a long period of years that antimony cannot be substituted for tin beyond 7% of the tin content without damage to some of the useful qualities of solders.[38] Alloys containing large quantities of antimony have been marketed (not listed in the Table), but with unsatisfactory results. In no case can antimony be expected to substitute for a really substantial proportion of the tin used in soft solders. The alloys containing up to 7 per cent Sb, as is indicated in the Table, are entirely satisfactory for general use, and for some purposes are superior to the binary alloys because of greater strength at elevated temperatures and a slower creep rate.

Cadmium: Cadmium can be substituted for tin in rather larger proportions than can antimony, partly because alloys higher in lead can be used when cadmium is present. This is done at some sacrifice of good working qualities and with a little loss in the strength of the joints formed. In the Table the alloys containing between 65 and 80 per cent Pb with 10 to 26 per cent Cd appear most promising. Within this range cadmium can be substituted directly for tin with no serious loss except in the tensile strength which is often unimportant. The lead-tin-cadmium alloys generally show a desirable rise in the capillary test and are well suited for soldering where a capillary action is employed. All are subject to rather severe oxidation when overheated; particularly is this true when the tin content is very low, i.e., below about 10 per cent. Cadmium oxide is poisonous and creates something of an industrial hazard. Moreover, there is a tendency for the oxide to become trapped in the joint with a resulting decrease in mechanical properties and an increase in porosity. Low temperatures are, therefore, to be recommended for handling these alloys. Where they can be used, a considerable saving of tin can be effected at slight inconvenience and some increase in cost. Special attention is directed to Alloys No. 29 and 31, which appear the most promising.

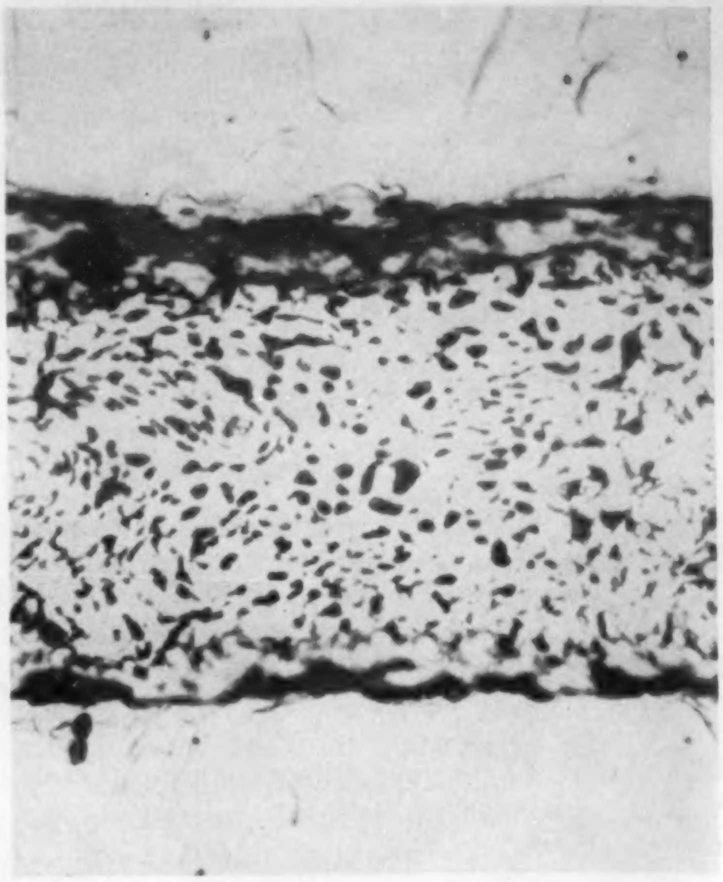
Bismuth: Lead-tin-bismuth alloys, while more difficult to handle than the standard solders, are capable of producing acceptable joints. (See the Table.) Their principal disadvantage lies in their low melting points, which give rise to low strength above room temperature. Where this feature is not objectionable, bismuth may be used as a major constituent of soft solders. Lower lead contents must be used with bismuth so that the saving of tin is not directly proportional to the bismuth added. Several combinations containing both bismuth and cadmium have also been tested and these appear to give somewhat superior shear strengths, but use unduly large proportions of tin. The cost of bismuth is high, however, and considering with this the other disadvantages it is hardly to be expected that bismuth solders could be economically used except under extraordinary circumstances.

Zinc: The addition of zinc to lead-tin solders has generally proven unsuccessful. A great deal of dross forms during the working if the zinc content is at all high. Moreover, zinc interferes seriously with the wetting qualities of solder and markedly decreases the corrosion resistance; notice in particular Alloys Nos. 45, 46, 47, 54, 55, 56, 57, 63, and 71 in the Table. No substantial saving of tin is likely to be effected by the substitution of zinc.

Mercury: Mercury has been used only for obtaining solders with low melting points and is never added in major quantities; see Alloys No. 60 and 61. When it is present, distinctly larger lead contents may be used with excellent results, and in this way mercury solders can be regarded as tin solder substitutes. With a probable shortage of mercury during the war times, however, it seems unlikely that these alloys will be acceptable. Moreover, the handling of mercury alloys at soldering temperatures might prove detrimental to health.

While the alloys made without the use of any tin are distinctly less promising than those containing reduced quantities, there are several combinations that deserve special notice.

Lead-cadmium solders: Foremost among these are the alloys based upon lead and cadmium. They produce joints of acceptable strength and can be handled satisfactorily if precautions are taken against oxidation, that is, if the working temperatures are kept as low as possible and care is exercised in fluxing. Unfortunately all of these alloys melt at rather higher temperatures than do the tin-lead-cadmium alloys; see the Table. Some special techniques by which oxidation is altogether avoided without the use of flux have been developed for handling the lead-cadmium alloys in special applications; for example, a leaf of solder may be subjected to heat and pressure between the surfaces to be joined. Under ordinary circumstances these solders characteristically form heavy brown oxide coatings. It seems altogether probable that they could be satisfactorily employed now in many places where tin-base solders are being used, but with some delay in establishing the most suitable working conditions.



Structure of a joint between copper rods soldered with a tin-lead solder. The centered band is a solder and the white outer bands copper. At the junction between the solder and copper, alloy layers can be seen. Etched with ammonia and hydrogen peroxide. 400X.

Cadmium-zinc solders: The cadmium-zinc alloys exhibit many interesting properties; they make joints of acceptable strength and are not subject to the severe oxidation exhibited by the lead-cadmium series; Alloy No. 56 exhibited the highest shear strength of any composition tested, half again as large as the best tin-lead solder. Their chief disadvantage lies in the difficulty of tinning the joints. Possibly, by the use of special techniques this trouble could be overcome. The quantity of cadmium used is considerably higher than in the lead series with a consequently higher cost. For this reason these alloys are less to be recommended except where a high shear strength is of paramount importance.

Lead-silver solders: Lead-silver alloys have recently received considerable attention and are being successfully used in a number of applications. They give joints of moderately good strength but unattractive in appearance. The working temperatures are rather high; this is compensated for by the advantage of a somewhat higher strength at elevated temperatures. Except for the high cost, these alloys seem well suited for substitute solders, and the price differential is not prohibitive.

Summary

A table has been made of the alloys which have been proposed as soft solders and as substitutes for the standard tin-lead compositions. It has been pointed out that no one alloy can be expected to serve all of the purposes now served by the tin-base alloys, and that a group of alloys covering the various needs must be employed.

All of the alloys listed have been subjected to a series of standard tests for comparison, so that compositions possessing those particular characteristics of the tin-base alloys that may be desired can be readily selected. These tests have all been made with reference to copper as the metal being joined.

It appears, on the whole, that the alloys containing reduced amounts of tin rather than tin-free solders will be found most acceptable for soldering copper. Among these the tin-lead-cadmium combinations appear most promising. Some compositions of outstanding merit have been pointed out. Of the alloys containing no tin, the lead-cadmium and lead-silver series are most attractive. Cadmium-zinc alloys and tin-lead-bismuth combinations should also find some domains of special usefulness.

Acknowledgment: The authors wish to acknowledge the contribution of Eugene Hughes who assisted with the tests.

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Low Alloy Steel Castings

from Available Raw Materials

For several years there has been in production a group of low alloy steel castings, somewhat analogous to the low alloy, high strength wrought steels, which have been widely discussed and are extensively used. Very little has been published on these low alloy steel castings, though we have tried repeatedly to survey this group. In general the steels in regular production are the medium manganese, the low nickel, the Ni-Mn, the Ni-Cr, the Ni-Cr-Mo, the Ni-Mo and the Ni-V as described in Table I of this article. There is also a special titanium steel, quite in favor.

Under present circumstances the production of these steels is difficult, due to the strategic situation of most of the alloying metals enumerated above. This valuable and timely discussion points the way out. It was presented at a meeting of the Southern California Chapter, American Foundrymen's Association Regional Conference, late in May, this year.
—The Editors.

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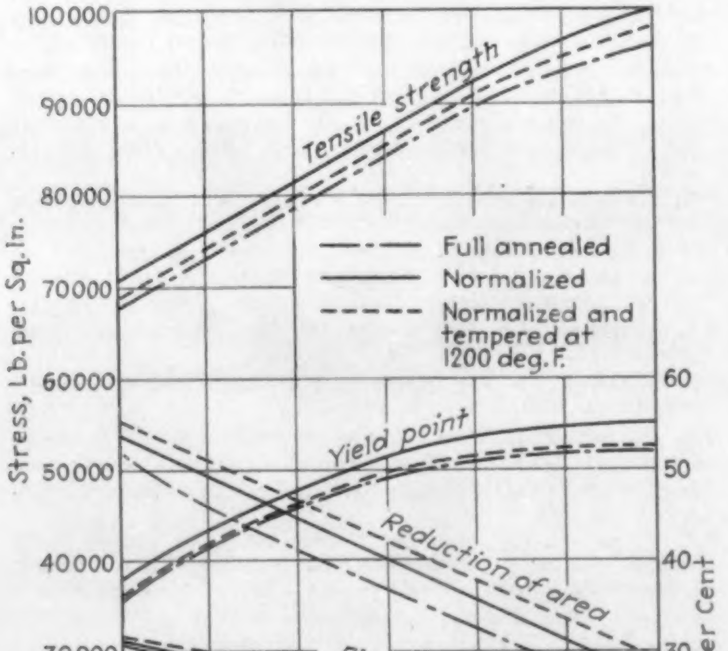
IN ORDER TO CONSERVE our supplies of some of the more strategic alloying metals, the steel industry and its customers are confronted with the problem of utilizing more readily available materials. The customer can generally use some substitute steel, provided that that substitute is tailored to his individual needs. These needs are not confined to the mechanical properties alone. They also include suitable machinability and suitability to the heat treatment and the degree of control for which his heat-treating furnaces are adapted, for new furnaces and new machine tools are not available for prompt delivery.

Fig. 1. The comparison of the fully annealed, normalized, and normalized and tempered, properties of medium carbon cast steels. (From Steel Castings Handbook, Steel Founders' Society of America, 1941.)



The producers of steels for wrought and forged products, with their own production problems, cannot do much tailoring. They cannot put a 100-ton furnace on the job of making 20-ton heats, nor is it feasible to route a lot of special compositions through the rolling mill without wasting time in keeping them separate.

The situation is different with the steel foundry. Its customers seldom care what the chemical composition of a casting is, as long as it is sound and has the desired mechanical properties. The small melting furnaces give utmost flexibility. Steel castings can be tailored to taste, not only from the point of view of providing materials specially fitted to the particular service concerned, but also to take advantage of the ebb and flow of availability of raw materials. Moreover, by production of castings of especially good properties there is today the opportunity of supplying castings for purposes formerly served by forgings.

If neither cost nor availability were an object, the steel foundryman would probably use such steels as those shown in Table I. (The properties cited for these, and for other compositions discussed later, unless other sources are stated, are taken from the excellent "Steel Castings Handbook" of the Steel Founders' Society of America.)

For reasons of cost, the steel foundry has used the medium manganese type rather than the nickel steels as its mainstay. The properties of this type of steel are shown in Table II.

The straight manganese steel, despite its ductility, tends to be low in impact resistance, and a sufficient manganese content for very high yield strength, without the presence of corrective elements, accentuates the poor impact behavior, and introduces trouble from castings cracking in the mold. Hence the tendency is toward holding manganese from 1.00 to 1.20 per cent with additions of molybdenum or chromium to increase yield strength, or to use with the high manganese additions such as vanadium or titanium to produce fine grain, as well as improved yield, or the use of nickel together with the manganese, as shown toward the end of Table II.

In terms of alloying behavior, nickel goes to the ferrite and strengthens without loss of toughness. Manganese, chromium, and molybdenum are carbide formers and only a part of the added alloy goes into the ferrite. They tend to boost strength, but at some loss of toughness. The salvation of the nickel-free steels lies in the use of vanadium, titanium, or some analogous grain-refiner to restore toughness through small grain size. The higher coarsening temperature produced by such additions allows greater latitude in the normalizing temperature. This is a point bearing on heat-treating practice that the foundryman might easily take advantage of if he looks toward overcoming fluctuations in properties that come from not too close control of his heat-treating furnace.

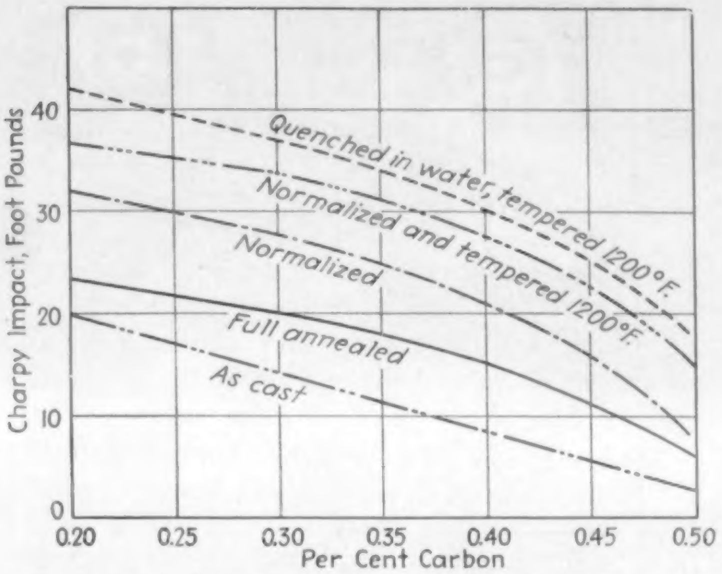


Fig. 2. The Charpy impact properties of medium carbon cast steels. (From Steel Castings Handbook, Steel Founders' Society of America, 1941.)

In seeking equivalent steels without nickel and with as little managanese as possible, so as to avoid the need for elements of present or potential scarcity, one looks first to ferrite-strengthening, non-carbide forming elements, so as to come as nearly as possible to the effects supplied by nickel. Such elements are copper and silicon, neither of which is likely to be permanently scarce. Both domestic and South American copper are available and the steel foundry could utilize such a variety of forms of silicon that any temporary scarcity of ferrosilicon could be tided over.

For strengthening, small amounts of chromium

Table I.—Tailor-Made Alloy Steel Castings

Composition, Per Cent							Normalized From, Deg. F.	Drawn at, Deg. F.	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent	Izod Impact, ft.-lb.
C	Si	Mn	Ni	Cr	Mo	V							
0.30	0.35	0.90	2.15	...	...	...	1650	1200	103,000	62,500	25	50	...
0.32	0.35	0.90	1.33	0.79	...	...	1650	1250	100,000	60,000	22.5	43	...
0.30	0.35	0.90	1.45	0.54	0.21	...	1650	1200	104,000	79,000	22	46	...
0.29	0.35	0.90	1.82	...	0.35	...	1650	1200	92,000	65,000	22.5	47	...
0.32	0.39	1.15	0.67	...	...	...	1650	1275	94,500	57,000	24.5	48	...
0.31	0.35	1.60	1.37	...	...	...	1550	1200	101,000	68,000	24.5	56	...
0.24	0.29	0.74	1.29	...	...	0.10	1725	1200	81,500	64,000	30.5	61	71

Table II.—Medium Manganese Steel Castings

Composition, Per Cent						Normalized From, Deg. F.	Drawn at, Deg. F.	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent	Izod Impact, ft.-lb.
C	Si	Mn	Mo	V	Ti							
0.35	0.33	1.25	...	...	...	1600	1250	85,000	50,000	28	50	25
0.32	0.48	1.54	...	...	...	1650	1250	96,000	60,000	24	54.5	...
0.34	0.40	1.68	...	...	...	1550*	700	103,000	55,000	25	51	21
0.31	0.35	1.02	0.50	...	...	1700	1200	99,000	71,500	20.5	53	36
0.32	0.35	1.15	0.34	...	...	1700	1250	94,000	65,500	24	49.5	...
0.33	0.35	1.52	...	0.11	...	1650	1200	100,500	67,000	27	55	41
0.30	0.40	1.60	...	...	0.04 (added)	1650	1200	96,500	72,000	25.5	56.5	45
			Cr									
0.32	0.68	1.14	0.47	0.20	..	1650	1200	97,000	71,000	28	60	...

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* Fully annealed, then normalized.

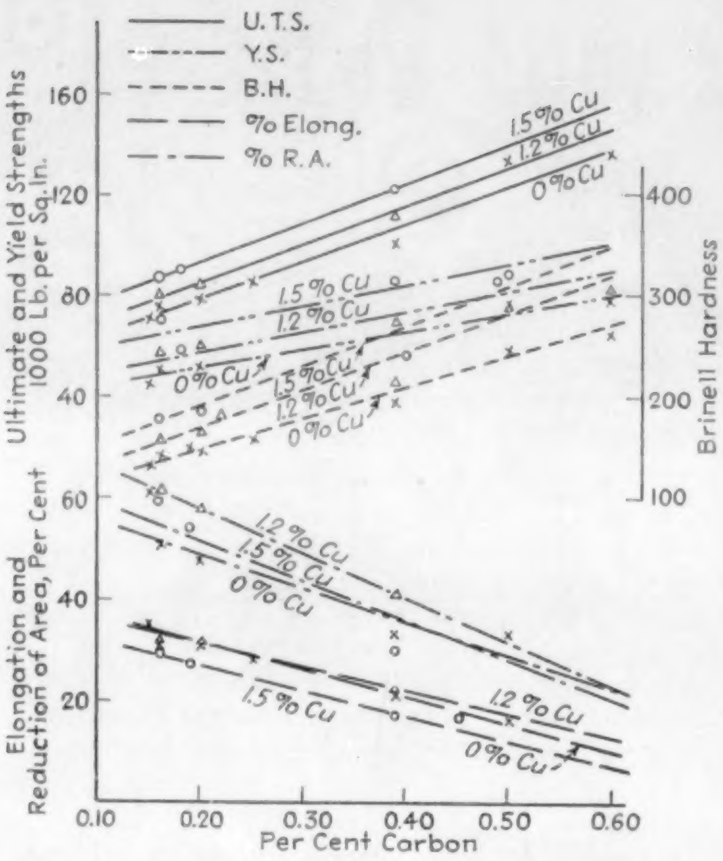

Fig. 3. The relation of mechanical properties of normalized cast steels to the carbon and copper contents. (Battelle, from work for Copper and Brass Research Assn.)

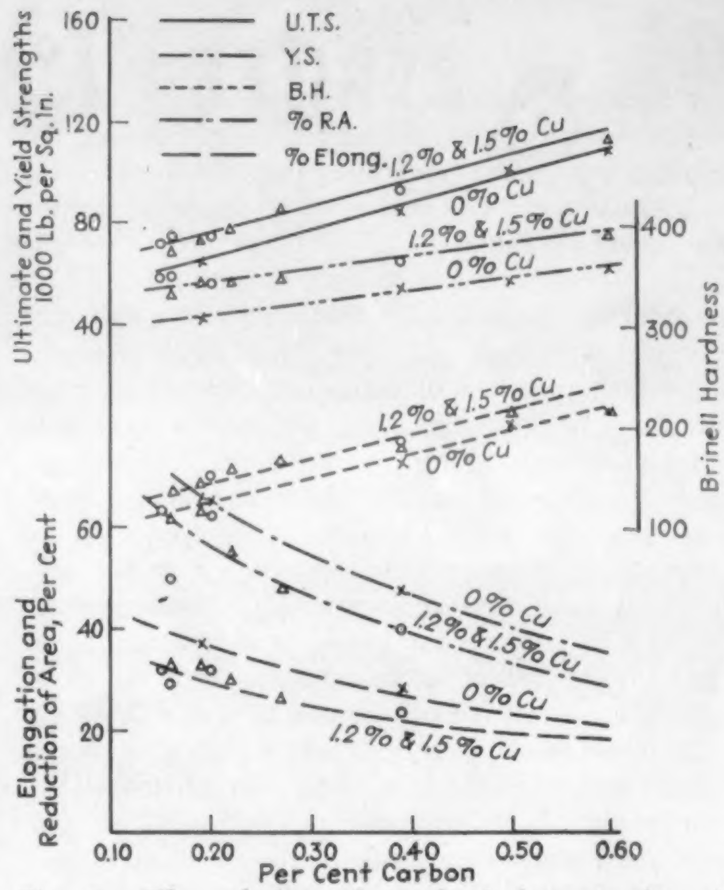

Fig. 4. The relation of mechanical properties of normalized and drawn cast steels to the carbon and copper contents. (Battelle, from work for Copper and Brass Research Assn.)

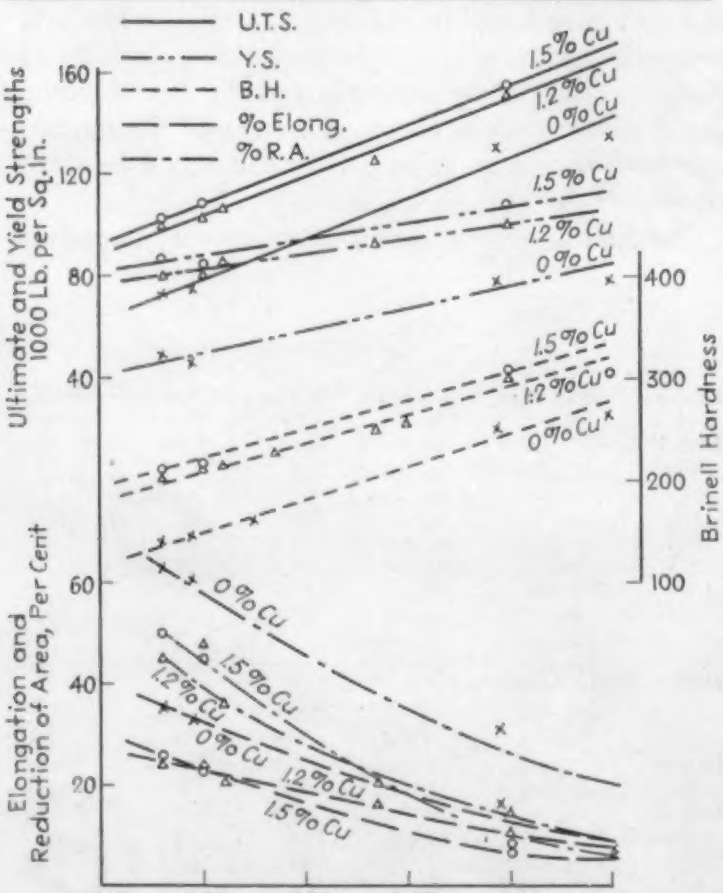

Fig. 5. The relation of mechanical properties of normalized and aged cast steels to the carbon and copper contents. (Battelle, from work for Copper and Brass Research Assn.)

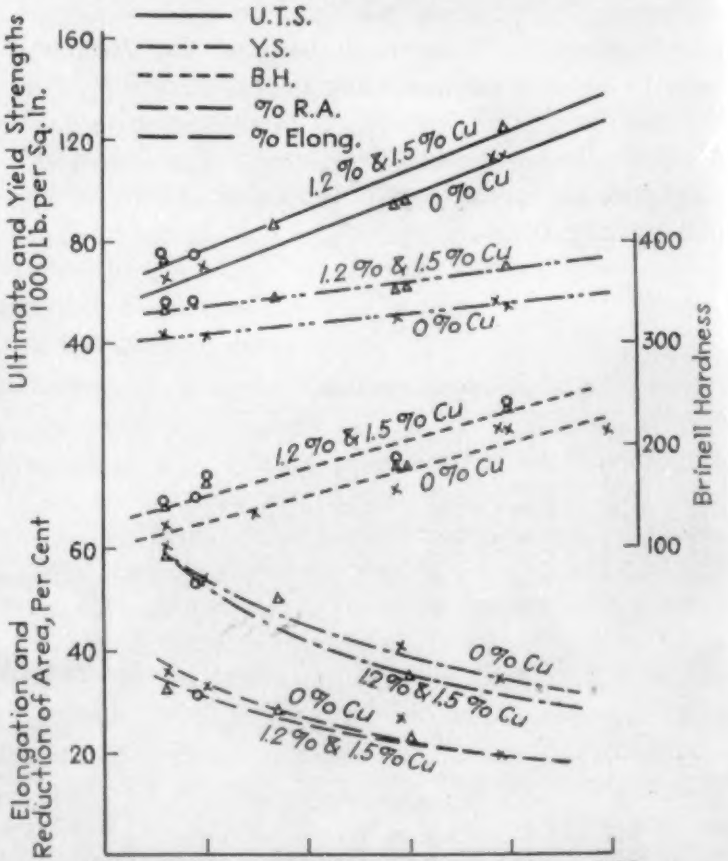

Fig. 6. The relation of mechanical properties of fully annealed cast steels to the carbon and copper contents. (Battelle, from work for Copper and Brass Research Assn.)

could be used when it is available, but molybdenum is the best bet on the score of probable continued availability because its oxide can be produced by merely roasting the concentrate, and the oxide is as suitable as the ferro for introduction of molybdenum into steel. There is another reason for paying special attention to copper and molybdenum. Both these elements are less oxidizable than iron, they can be added to a melt at any stage without loss and without effect on the slag or the steel refining process. Scrap can be remelted without loss of copper or molybdenum. The scrap can be put through a cupola and the hot metal used for converter steel. Cupolas and converters can be installed more quickly and cheaply, when production must be increased, than electric or open-hearth furnaces.

In the case of converter steel what small amount of chromium it might be desirable to utilize in ordinary cast steel could be added by the Chrom-X method to the ladle. Low grade ores could be used for making a ferro-chromium of lower than usual chromium content, which would also be applicable for making the small chromium addition.

Supplies of ferro-carbon-titanium or of ferro-vanadium are needed whether we use the nickel or manganese base or whether we go to the substitutes, but since either titanium or vanadium can be used, and zirconium would serve in almost identical fashion, and since only a small amount of any such addition element is required, it should be possible to dodge around a shortage in the supply of any one.

It goes without saying that when liquid quenching and tempering are applicable, it may not be necessary to resort to any alloy at all, and it is true that liquid quenching is being successfully applied to castings with such differences in section that the foundryman of a few years ago would have despaired of any possibility of a successful quench. Yet limitations do exist, such that alloying cannot be dispensed with.

Indeed, production requirements demand that steel castings be made of compositions amenable to a single normalize plus a draw, without requiring full annealing or double normalizing, unless a particularly heavy section demands that double normalizing be applied to produce a good structure, no matter what composition is used.

It is possible to obtain some increase in yield strength of normalized and drawn unalloyed steel by raising the carbon, though this is attended by lowered ductility and impact resistance, features that are of minor engineering importance in many uses so that the emphasis on ductility is often more of a fetish than a real engineering need. However, not very much can be done in boosting the yield strength by carbon as Figs. 1 and 2 show. A yield strength of 52,000 lb. per sq. in. is maximum for normalized and tempered unalloyed steel.

One type of steel, using a bit higher manganese than is desirable from the point of view of strategic substitution, but making good use of the ferrite strengthening effects of copper and silicon is due to

*Table III.—Low Alloy Steel Castings**

Composition, Per Cent				Annealed at Deg. F.	Normalized From, Deg. F.	Precipitation Hardened at, Deg. F.	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent
C	Si	Mn	Cu							
0.11	1.23	1.04	1.74	1740	....	...	81,500	64,000	31	56
0.11	1.23	1.04	1.74	1740	1580	915	106,500	88,500	25	53

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* Finlayson, A.: Low Alloy Steel Castings in Logging and Road Construction, METALS & ALLOYS, vol. 8, 1937, pp. 239-244.

Table IV.—Complex Copper Steel Castings

Composition, Per Cent *					Treatment	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent	Charpy Impact, ft.-lb.
C	Si	Mn	Cu	Mo						
0.20	0.54	0.82	1.68	...	Normalized	94,000	71,000	24.5	53	22
					Normalized and reheated for precipitation hardening	113,000	87,000	21	48.5	13.5
0.20	0.33	0.66	1.60	0.30	Normalized	93,000	60,000	21	41	11
					Normalized and reheated for precipitation hardening	121,000	92,000	18	38	10

Composition, Per Cent **						Normalized From, Deg. F.	Drawn at, Deg. F.	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent	Izod Impact, ft.-lb.
C	Si	Mn	Cu	Mo	Ti							
0.32	0.40	0.80	0.95	0.22	...	1550	1100	93,000	64,000	22.5	50	...
0.28	0.37	1.07	1.02	...	0.20 (added)	1700 then 1600	750	94,000	72,000	27.0	52	40
0.29	0.30	1.18	1.38	...	0.05 (added)	1600	none	103,500	79,000	23.5	46	23

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* Data from discussion of paper "The Effect of Mass Upon the Mechanical Properties of Cast Steel." Briggs and Gezelius, *Transactions* A.S.M., vol. 26, 1938, pp. 395-396.

** Data from unpublished work at Battelle.

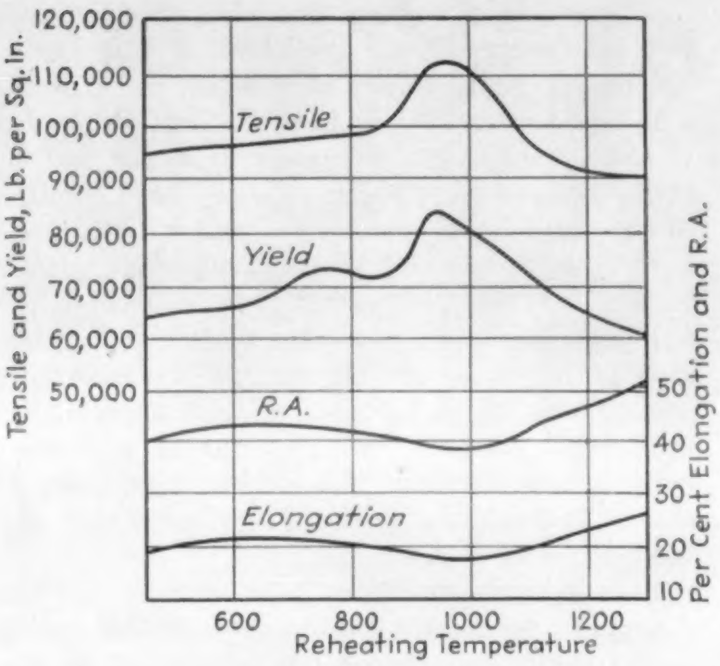

Fig. 7. Effect of reheating for 4 hrs. at temperatures shown, on a steel of 0.56 per cent C, 1.03 per cent Cu, normalized from 1490 deg. F. (From "Steel and Its Heat Treatment," Bullens and Battelle, 1939.)

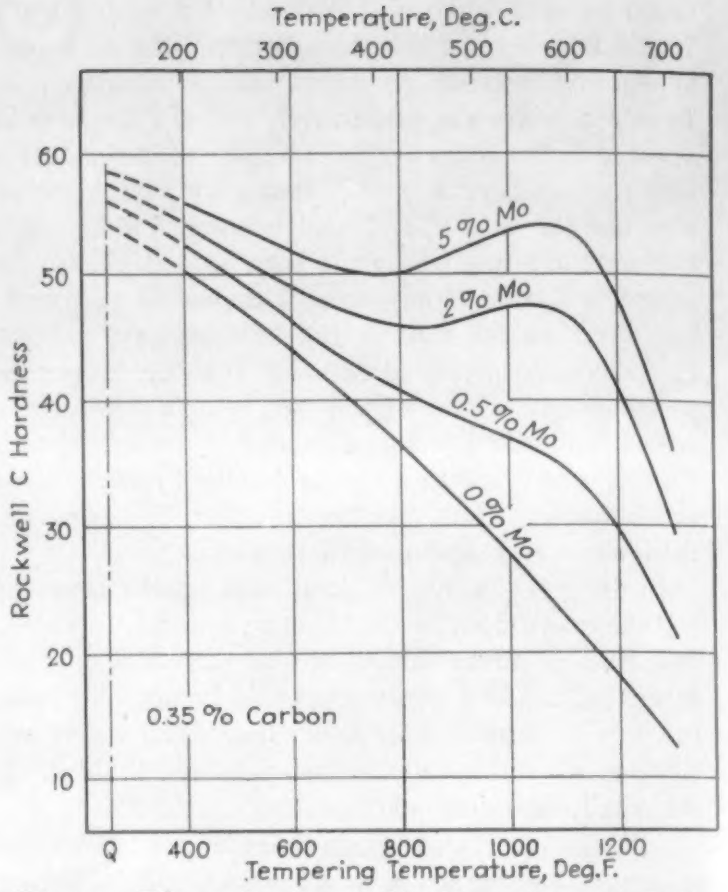

Fig. 8. The softening, with increasing tempering temperature, of quenched 0.35 per cent C steels as influenced by molybdenum content. (From Bain, "Functions of the Alloying Elements in Steel," American Society for Metals, 1939.)

Table V.—Copper-Bearing Cast Steels

	Composition, Per Cent					Normalized From, Deg. F.	Drawn at, Deg. F.	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent	Izod Impact, ft.-lb.
	C	Si	Mn	Cu	Ti							
A *	0.28	0.40	1.18	1.05	0.05	1600	1150	97,000	72,500	25	51	25.5
B *	0.29	0.31	1.30	1.10	. . .	1600	none	102,500	67,000	24.5	52	32.5
C *	0.28	0.32	1.11	1.10	0.05	1600	700	96,000	67,500	28	55.5	48
D *	0.29	0.34	0.66	1.24	. . .	1700, 1600	1200	80,000	58,000	30	54.5	36
E *	0.32	0.37	0.78	1.22	. . .	1650	1150	94,000	67,000	22	47	23
F **	0.25	0.35	0.66	1.26	0.05	1700, 1600	1200	79,000	62,500	30.5	58	51.5
G **	0.25	0.33	0.65	1.28	V 0.15	1700, 1600	1200	88,500	71,500	26.5	55	41
H **	0.21	0.34	0.61	1.27	Zr 0.10	1700, 1600	1200	76,500	59,500	31.5	66	68.5
I **	0.22	0.33	0.71	1.28	Mo 0.19	1700, 1600	1200	74,500	59,000	32	61	68.5
J ***	0.26	0.40	0.80	1.30	0.10	1650, 1575	1250	88,000	63,500	28	62	57

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* Greenidge and Lorig, "Properties of Some Copper-Bearing Cast Steels," *Transactions*, American Foundrymen's Association, vol. 47, 1939, pages 229-256.
** Battelle, from unpublished work.
*** From "Steel and Its Heat Treatment," Bullens and Battelle, 1939, vol. II, page 107.
Note: Steel J also contained 0.50 per cent chromium.

Table VI.—Effect of Drawing Temperature on Copper-Molybdenum Cast Steel

Composition, Per Cent						Normalized From, Deg. F.	Drawn at, Deg. F.	Tensile Strength, lb. per sq. in.	Yield Strength, lb. per sq. in.	Elongation in 2 in., Per Cent	Reduction of Area, Per Cent	Izod Impact, ft.-lb.
C	Si	Mn	Cu	Mo	Ti							
0.27	0.41	0.58	1.21	0.20	0.05 (added)	1600	400 (14 hr.)	99,000	66,500	23	40	21.5–26
						1600	700 (1 hr.) 400 (14 hr.)	98,500	66,000	21	40	18 –21
						1600	1000 (1 hr.)*	113,000	86,500	12	5–17	9 –10.5
						1600	1225 (1 hr.) 400 (14 hr.)	87,500	69,000	23	50	25 –27.5

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* Precipitation hardened.
Note: 400 deg. F. draw treatment used for hydrogen removal, since the bars were tested soon after casting.

Finlayson. (Table III.) This is a very fluid steel, and very complicated castings from it have shown up well in extremely severe service.

Copper, by itself, goes part way toward giving the desired properties but may need the help of some other element. Figs. 3 to 6 inclusive give information on plain copper steels, and Table IV adds data on copper in the presence of some other alloys.

Because of the precipitation hardening effect of copper, normalized steels with over 0.75 per cent Cu will become stronger and less ductile if drawn in the range 850 to 1100 deg. F. For greatest toughness a stress relieving draw at 750 deg. F. or a softening draw at 1150 to 1250 deg. F. will be used while for increased yield strength a 950 deg. F. draw can be applied. This pattern of behavior is shown in Fig. 7. This phenomenon is met in the 0.75-1.50 per cent Cu steel irrespective of the other alloying elements present.

In this connection it may be noted that at 800 to 1200 deg. F. there is an analogous precipitation hardening effect of molybdenum, which opposes the softening effect of a draw after normalizing, so that molybdenum containing steels are ordinarily drawn for toughness at 1200 to 1250 deg. F. Fig. 8 brings out this effect. In the usual small amount, 0.20 to 0.50 per cent, in which molybdenum is ordinarily added to the type of steel under discussion, this effect is not outstanding, but it does affect the choice of draw temperature. By choosing the right draw temperature the molybdenum steels can be improved in toughness and impact without much loss of yield strength.

Much of the early work on copper steels was done with the manganese-copper combination, since the problem of substitution for manganese was not then acute. Some of these data are given in Table V.

In order to evaluate the behavior upon single normalizing of a copper-molybdenum steel of normal manganese content, when suitably treated with titanium, a steel was prepared as shown in Table VI. This steel, or as an alternative to molybdenum, the higher manganese steel "C," or the chromium steel "J," in Table V, offers yield strength, ductility and impact resistance comparable to the nickel containing or the medium manganese cast steels.

The use of titanium, or as alternatives vanadium or zirconium, is essential to best results. The mechanism involved appears to be primarily in preventing grain coarsening of austenite on heating for normalizing. In the case of titanium and, perhaps, for the other grain refining elements, there is a "fixation" of nitrogen, and the nitride particles may play a part in preventing grain coarsening.

It may, off-hand, appear that priorities and instructions to seek substitutes for strategic alloying elements are asking the steel maker to do a job outside his reach, but so far as the flexible steel foundry is concerned, it is quite feasible to make steels, using available raw materials, that fulfill the needs of its customers as to mechanical and engineering properties.

Editorials *(Continued from page 685)*

atmospheric corrosion resistance of most of the mild alloy steels and the fact that things usually are painted, this argument has never impressed us as the correct main talking point for this class of steels.

In the main we agree with Foote that the railroads are missing a good bet, and that defense production would be aided by building the new freight cars out of mild alloy steels. Yet the overall combination of economics and psychology in the freight car game doesn't make that the easiest field to break into. It does seem serious that the mills have laid the mild alloy steels pretty much aside, for they fill real needs. Indeed, one answer to Foote's question "for whom and for what" is given in *Railway Age* in a note starting on the same page on which Foote's article ends. The note is headed "New 250-Ton Wrecking Crane," and goes on to say that this, the largest such crane ever built, obtains its large capacity, without exceeding railway limitations of size and weight, "through the use of high strength alloy steels."

It's desirable that these steels be available for and be used in freight cars, but it's vital that they be available for such uses as in the crane.—H.W.G.

Aluminum

The reduction in the price of aluminum to 15 cents per pound, recently announced by the Aluminum Co. of America, is the fourth since 18 months ago at which time it was 20 cents. Fifty years ago, when the metal was first produced by the Aluminum company, the price was $8 per pound. At that time the volume of output was only 9,000 pounds a year. As a result of the demand and of the present Defense Program, of the investments of the company itself, and of the Government in leased plants, the Aluminum company's production of the metal will soon approximate 550,000 net tons (1,100,000,000 lbs.) annually. This will be 120,000 times what it was 50 years ago—a remarkable expansion and one not approached for any other metal in a like period, except possibly molybdenum which shot up from a few hundred pounds at the start to present levels. It is probable that the percentage increase would equal that of aluminum.

In announcing the last price reduction to 15 cents, the Aluminum company states that it is made in anticipation of the economies from the building of new plants and of the company's $200,000,000 expansion program begun in 1938 and now nearly completed. Mass production in any field should result in economies in the costs which in all fairness should be passed on to the consumers.

In the case of aluminum as well as in some other metals, one cannot refrain from speculating on what the situation will be when this emergency is over. Will the supplies of aluminum, magnesium, and so on, be so large that they will exceed the demand by a large margin? Will this result in still lower prices or will new uses be found to absorb the bulk of the metals? Surely these are unanswerable questions just now, but they point the way to intensive research by the metallurgical engineer.—E.F.C.

Putting Idle Equipment to Work

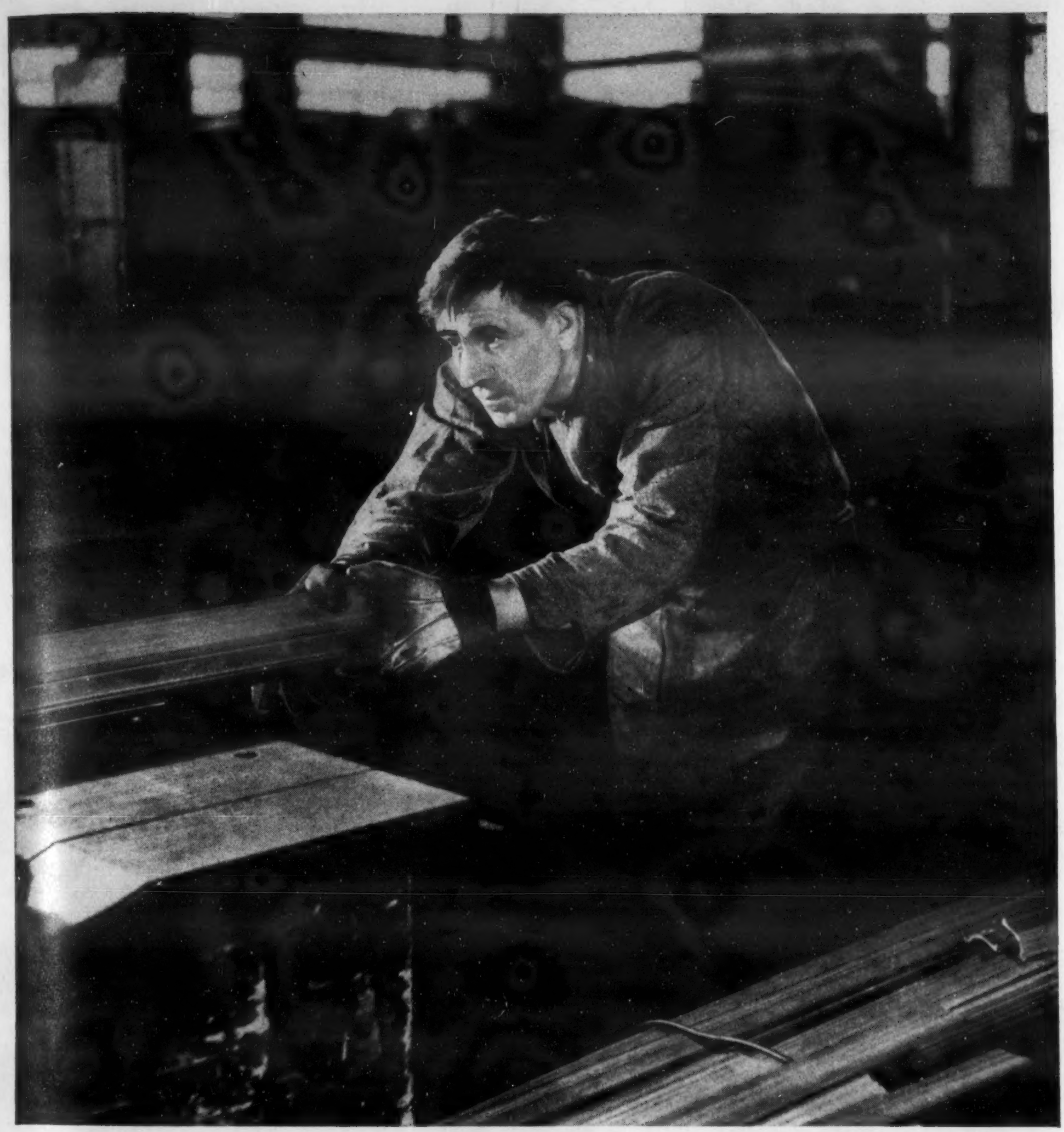
With industry—and particularly the metal-producing and metal-working industries—pushing its total production to heights beyond the level of even a 1929 optimist's imagination, it is distressing to learn occasionally of companies with idle specialized-manufacturing facilities that are just aching to be put to use.

The condition we refer to is not the unnatural and enforced idleness of raw-material stoppages, but the "normal" situation of a plant equipped for a highly specialized operation (powder metallurgy pressing, for example) that it customarily performs only irregularly or experimentally. In ordinary times, the idle periods are not "viewed with alarm" (except perhaps by the plant's accountants), but today, with other companies almost certainly in great need of just such facilities, some method should be evolved to put the shop with sometimes-idle specialized equipment in touch with other shops that could really use it.

The editors of METALS AND ALLOYS will be happy indeed to act as a "clearing-house" for contacts of this nature. In other words, if your plant includes a department or contains perfectly good equipment (for melting, casting, pressing, shaping, treating, joining, finishing, testing, or other metallurgical engineering operations) that is sometimes idle and which you'd like to see used, just send us a brief description of such facilities and the length and frequency of continuous periods for which they might be rented.

Or, on the other hand, if your problem is an acute need to do small-lot or occasional specialized work—say high-frequency melting, or special heat treating, or briquetting, or furnace-brazing, or metallographic inspection, etc.—on equipment that you don't have and wonder who has, write us a letter outlining your requirements.

Then, wherever the shoe fits, we'll immediately put the "where-can-we-find-one" shops in touch with the "how-can-we-use-it" plants. If people in both groups really cooperate in the way suggested, we feel sure that much can be done to expedite production that is now jammed through lack of knowledge of the location of specialized facilities.—F.P.P.



A TRUE EYE FOR BRASS. In every department at Revere Copper and Brass Incorporated you will find men who have a "knack" for brass. Men like Peter Gura, for instance, who has been with Revere for thirty-five years—a man whose eye can tell to a hair when a brass shape is out of true, and who can set it straight as a plumb line with a practiced twist of his hands. In operations such as this, which would baffle a machine, Revere sees an opportunity to put an extra ingredient—the *human touch*—into copper and copper-base alloys. That is one of the many reasons why Revere materials are so trustworthy in strengthening America's defense, and why the end of the emergency will find Revere so well prepared for the advancing needs of industry. Revere Copper and Brass Incorporated, 230 Park Avenue, New York.

Female Woodcock on nest: easy to photograph, not easily distinguished.
—W. Bryant Tyrrell

Hatching TOMORROW'S POSSIBILITIES

Powder metallurgy has been in a process of quiet incubation for a good many years . . . "protectively colored" from general observation. To be seen, of course, were some of its evidences: the tungsten lamp filament; diamond impregnated grinding wheels; porous metal bearings — among others. Now, suddenly it seems, there emerges a great awareness of powder metallurgy's promise as a method for making many metal parts and materials.

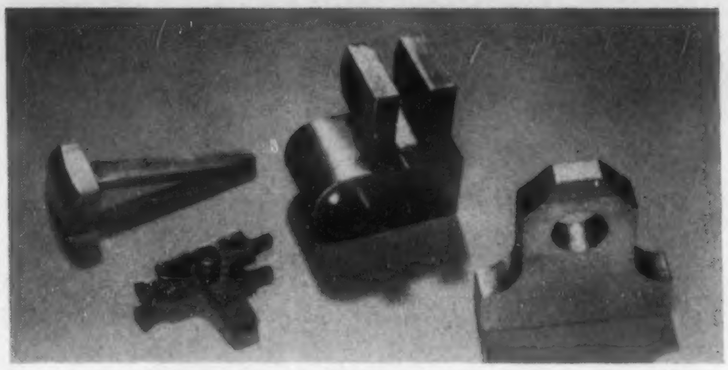
Need for replacement materials has helped intensify interest in Powder Metallurgy's new and larger role. Metals Disintegrating Company, manufacturer of all kinds of metal powders through 25 years, is making new materials practical to use. Iron powder, for example: pistons of powdered iron are now replacing aluminum pistons in hydraulic brakes.

Our unique experience in this field has proved helpful to many a manufacturer with a powder application "hen on the nest." That experience of a quarter century—and familiarity with current developments in materials and equipment and processes—will be available to manufacturers seeking new advantages in *tomorrow's* markets.

METALS DISINTEGRATING COMPANY
MD
ELIZABETH
NEW JERSEY

METAL POWDERS SINCE 1916

Powder Metallurgy—1941 Model



A REPORT OF THE M. I. T. SUMMER CONFERENCE

by FRED P. PETERS
Associate Editor

EVER SO GRADUALLY, powder metallurgy is coming down to earth, turning its feet in straighter paths, and finding the going good. One still discovers in pronouncements from the field a noticeable admixture of airy claims with the solid, both-eyes-open examinations of progress and prospects, but the condition seems to be no worse, at last, than in other branches of metallurgical engineering.

All this is a mere reporter's reaction to the papers, discussions, private comments and "bull-sessions" that filled the two days and an intervening night of the second annual Powder Metallurgy Conference held at Massachusetts Institute of Technology, Cambridge, Mass., Sept. 25th and 26th, under the direction of Professor John Wulff. Thirteen papers were presented, including an outstanding discussion of die design factors, a report of a new "displacement" application of powder metallurgy (for glass-sealing alloys), a broad review of the iron powder situation, papers on processing techniques with iron powders and differences among such powders, a description of a new stainless steel powder, several useful reports on the properties of certain commercial products (cemented carbides, electrical contacts) made by powder processes and a few papers on fundamentals of powder behavior.

The attendance at the meetings ranged from 148 to 195, and a large part of the audience freely engaged in the discussions, for which adequate time had been arranged. In the following report, the papers are reviewed not necessarily in the order in which they were presented.

Design Factors in Powder Pressing

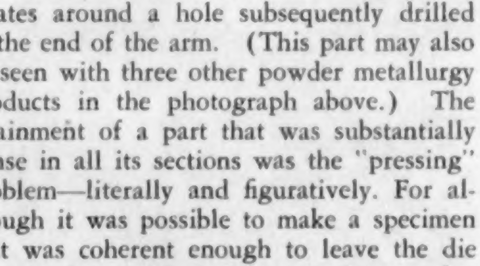
Design information—part design, die design, and "powder metallurgy design" as it differs from conventional-process design—continues to be a foremost need if powder metallurgy is really to be utilized to the fullest advantage by industry in general.

The great advantage of a combination of mechanical engineering and powder-metallurgical knowledge in the production of low-porosity machine parts by powder methods is evident from the data presented by R. P. SEELIG of Powder Metallurgy Inc., in his paper "Some Problems Involved in the Manufacture of Dense Powder Metallurgy Parts". The small but complex parts described approached technical density, and replaced machine parts formerly made by conventional methods.

For example, the part shown in Fig. 1 is a bronze piece used as a weight that rotates around a hole subsequently drilled in the end of the arm. (This part may also be seen with three other powder metallurgy products in the photograph above.) The attainment of a part that was substantially dense in all its sections was the "pressing" problem—literally and figuratively. For although it was possible to make a specimen that was coherent enough to leave the die in one piece, with satisfactory sintering behavior, the strength at the junction of arm and head was insufficient.

The amount of powder needed to make the arm was much less than for the head. Therefore, the lower punch had to be in 2 parts — one for the arm and one for the head — and the lower plunger for the arm had to be much higher in the die than the lower plunger for the head at the time of fill. When the upper plunger came down and pressure was exerted, good density in both head and arm was achieved, but their juncture was weak.

Fig. 1. A bronze part now successfully made by powder metallurgy (Seelig).



The problem was solved by careful balancing of the position of the lower plungers at all times in the cycle, so that the curve of relative movement obtained produced a strong part throughout. The part is made in 2 pressing and 2 heat treating operations. Close tolerances, particularly on the curved portions of the head, are required and met. The part is now being manufactured by powder metallurgy economically and rapidly, as compared to ordinary methods.

The bronze part in Fig. 2 was an interesting problem. Die design was based on a pre-determined compression ratio of 3:1, applied to both the wings and center section. Yet, no matter how the part was pressed, the wings and center section did not have the same density. On a mechanical press (which reverses after a predetermined travel) the wings would have lower density than the center; on a hydraulic press (which is reversed at a certain pressure) the wings would be too thin.

This shows that in such parts as this there is apparently some flow of the powder from the wings to the center, and by rebuilding the die it was possible to allow for it. The powder compression does not follow simple arithmetic. Considerable care, therefore, should be given to the design of dies for parts having substantially different thicknesses.

A good example of a tough ejection problem and its solution by special measures is found in the part shown in Fig. 3—a steel part formerly cut out of cold-rolled carburizing steel. Two punches are used in the bottom of the die. No movement can be permitted in the ejection stroke or cracks will form on the inside of the flange. Because the friction on the core rod surface increases the tendency to movement, it was necessary to design the set-up with the two punches practically locked together for ejection, to avoid the slightest movement.

These and other examples led SEELIG to formulate the following group of simple, sound, engineering principles to be applied to die design and construction for the

(Continued on page 722)

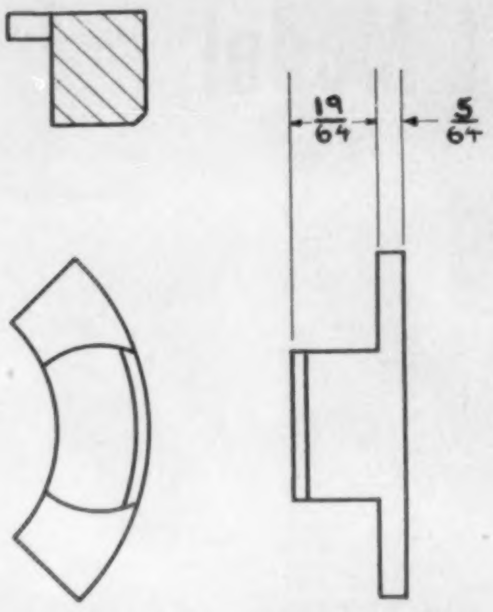


Fig. 2. A bronze powder metallurgy part requiring special care in die design (Seelig).

manufacture by high pressure of dense, strong and ductile powder compacts.

(1) If movable punches are used, they must be guided to eliminate motion except in the desired direction.

(2) If a punch has holes, grooves or other sectional changes, extra metal must be provided, where possible, to compensate for stress overloads.

(3) If it is necessary to press powder inside a movable die part, the latter should be designed with the strongest possible walls.

(4) A liberal taper should be provided wherever permissible to facilitate ejection and avoid cracking.

(5) Since a die cannot operate properly in a worn or unsuitable press, special attention should be given to selecting the best press for each specific job. In some cases, a mechanical press may be ideal, while in others the slower hydraulic press may be the wiser choice.

The discussion of SEELIG'S paper was as lively as the great importance of these types of data warranted. DEFOREST of M. I. T. mentioned the over-emphasis on ductility in general engineering practice, and pointed out that observation of the practical success of many low-ductility sintered parts might aid engineers in dispelling the illusion of ductility's importance.

GOETZEL of American Electro Metal Corp., seconding DEFOREST'S comment, explained that he had found the fatigue strength of sintered copper high even though the ductility was simultaneously low. Since this was the result of laboratory-scale work, it was interesting to hear from others that commercial powder metallurgy parts usually have even better properties than similar specimens made in the laboratory.

SISCO of the A. I. M. E. secretariat defended the design engineer against charges of poor design that really should be laid at the door of "the metallurgist" for not supplying adequate information about metal properties. Several men stressed, however, that the greatest lack was still *design* information, by whomever supplied—information that would permit the engineer to evolve special appropriate designs for powder metallurgy practice instead of attempting merely to modify existing conventional-practice design for a specific part. [Your reporter sees this confusion of responsibility gradually being resolved as the once separate functions of "design engineer" and "metallurgist", in cases like this, become merged in the increasingly familiar "metallurgical engineer"—an engineer who thoroughly understands *both* design and metallurgy.]

Workable Molybdenum-Iron Alloys

A new series of powder-pressed alloys that may replace wrought nickel-base alloys for certain radio tube and incandescent lamp applications was described by J. KURTZ of Callite Tungsten Corp. in a paper "Workable Molybdenum Iron Alloys." Because of a favorable coefficient of expansion, certain of the new alloys containing 10-20 per cent Mo, 1 per cent Cu and the remainder iron, seem destined for use as metal-to-glass seals, where the glass corresponds to the Corning G-1 type.

In his investigation, KURTZ studied iron-base alloys containing 5, 10, 15 and 20 per cent Mo and 1 per cent Cu, prepared (a) by pressing, sintering and working down into wire, and (b) by melting, casting, annealing, and similarly reducing to wire form. For the powder-processed pieces, —200 mesh pure metal powders were mixed, tumbled, pressed in a 3/8 in. x 3/8 in. x 14 in. mold at about 25,000 lbs. per sq. in. and sintered in hydrogen at 2200 deg. F. for 1 hr.

In general, powder metallurgy made possible alloys that not only duplicated in chemical composition those prepared by melting and casting, but which also had a finer grain size and easier workability by rolling, swaging and wire drawing than cast ingots of the same nominal analysis.

The workability seemed to be associated with precipitation within the alloy, for, of the cast ingots, only the 5 per cent Mo specimens showed no precipitation, and only these could be easily worked down. Of the sintered ingots, only the 20 per cent Mo alloy showed precipitation, and again, only this alloy gave difficulty in working down. This is important because the most desirable physical properties were found in alloys with 10 per cent or more molybdenum—those that are difficult to fabricate unless made by powder metallurgy.

The properties of the alloys as prepared by powder metallurgy are given in Table I.

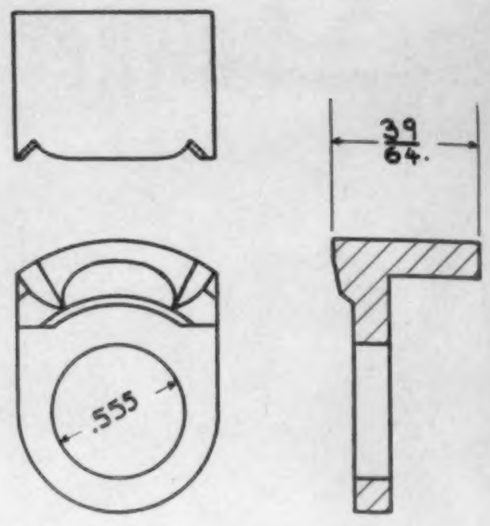


Fig. 3. An iron powder metallurgy part that presented a tough die-ejection problem (Seelig).

Iron Powder

For special alloy products like those described by KURTZ, the powder supply problem is not great, since the market for each individual item is limited in size. The potentially widespread market for *iron* powder is a different matter, and is still repressed to an indefinable extent by a currently limited supply. A broad review of the iron powder situation today was presented by A. H. ALLEN of *Steel* in his paper "Iron Powder", and it evoked long and vigorous discussion.

Allen outlined 7 basic methods tried or used for making sponge iron and iron powder, and reported that the metal powder field is practically convinced that a high purity (99+ per cent) good-molding-quality iron powder cannot be produced from ore, but must be made from scale, pig iron, scrap, etc., because of the high and tenacious silica content of the ores. The problem of obtaining high purity at a reasonable price is called the biggest present drawback to the more extensive use of iron powder.

It is estimated that about 15,000 lbs. of iron powder of different prices and purities is currently consumed per day. One source estimates that industry could use at least 50,000 lbs. per day of 99 per

Table I. Properties of Iron-molybdenum-copper Alloys Made by Powder Metallurgy

Alloy Type	5% Mo Alloy	10% Mo Alloy	15% Mo Alloy	20% Mo Alloy
Density (as sintered)	7.49	6.96	7.42	8.03
Per Cent Porosity (as sintered)	6.6	13.3	7.6	0.4
Hardness, Rockwell B, annealed	50	81	84	87
Tensile Strength, lbs./in.^{2}, annealed	62,900	74,300	79,900	——
Elongation, annealed	14%	14%	15%	——
Elec. Resistivity, ohms/mil-ft., annealed	159	256	266	——
Coeff. of Thermal Exp. per deg. C. 20-600 deg. C.	12.62	11.04	10.00	9.15

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cent Fe powder at a reasonable price. And this doesn't necessarily mean the lowest price, for one user states that iron powder of 99 per cent purity at 12 cents per lb. would be more economical than a 96 per cent powder at 8 cents a lb.

Allen classified the probable grades of iron powder in eventual production as (a) 99+ per cent purity, for bearings, electrical products, etc.; (b) 96-99 per cent pure, for large-production machine parts; and (c) less than 96 per cent, for even less strict requirements. He stressed, in addition, the importance of other factors, such as size, shape, sponginess, and uniformity of particles.

Practically everyone dove into the discussion. H. E. **Hall** of Metals Disintegrating Co., Inc., expressed his belief that the purity of iron powder is often overemphasized, except for high-magnetic-permeability work. **Wulff** of M. I. T. agreed, and cited the case of a higher-purity equivalent of Swedish iron that he found harder to press.

Claus of Bound Brook Oil-Less Bearing Co. explained that purity was often very important, but chiefly from the standpoint of the nature of the impurities, some of which may be objectionably abrasive. This was seconded by **Patterson** of Powder Metals and Alloys, Inc., who stated that a 97 per cent Fe might be preferred to a 99 per cent Fe if the particular impurities in the former were much less abrasive than those in the latter.

Interesting differences in sintering behavior between carbonyl iron and Swedish iron powder were reported by **Wulff**. He had found the carbonyl iron to be more "sinterable": pressed slugs increased in density on sintering at a temperature several hundred degrees lower than that at which Swedish iron briquettes began to sinter.

An explanation for this was offered by **Mullaly** of Advance Solvents & Chemical Corp., somewhat as follows: There is a considerable range of particle sizes present in a given grade of carbonyl iron powder, and the particles are generally spherical, rather than angular. On sintering, the smaller particles are able to fit into the spaces between the larger powders, giving more particle-mobility and also producing a denser structure—something like a lot of little ball bearings inside many bigger ones.

Hot Pressing of Iron Powders

Some of the differences among the various types of iron powder as revealed in their behavior on hot-forging and hot pressing were discussed in two complementary papers—the first by R. P. **Koehring** of Moraine Products Div., General Motors Corp. on "Hot Forging of Iron Powder Briquettes", and the second by C. G. **Goetzel** of American Electro Metal Corp., entitled "Hot Pressing of Iron Powders".

Koehring divided powder-processing methods into 3 groups: (a) cold pressing, sintering, and (if applied) sizing; (b) hot pressing; and (c) hot forging, which comprises pre-forming a briquette, heating it to the sintering temperature and immediately forging to shape in cold dies. The conventional method, (a), is a high production method for making parts to accurate dimensions, and, of course, is the only way of producing porous parts. The hot fabricating methods, (b) and (c), give the highest densities and strengths, but at some sacrifice of economy, production rates and dimensional precision.

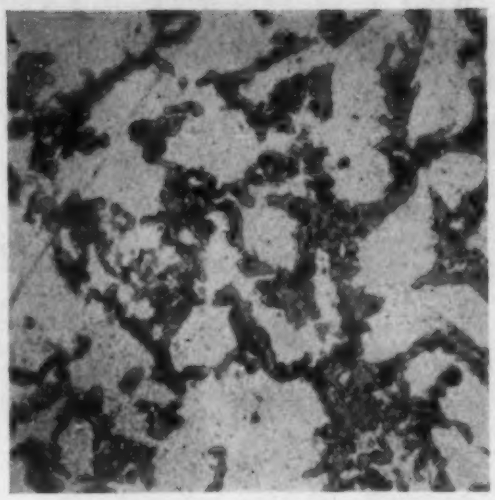

Fig. 4. Oxidized microstructure of a porous iron part treated in steam. 250X (Lenel).

The suitability of certain types of iron powders for hot forging operations was tested by **Koehring**, the results on ground S.A.E. X-1112 turnings, a decarburized iron-carbon alloy powder, and reduced-oxide powders being of special interest.

Hot forged samples made from the reduced-oxide powder had lower density than those made from decarburized iron-carbon powder. Pieces made from the latter also had high tensile strength, about 72,000 lbs. per sq. in. Parts hot forged from the ground S.A.E. X-1112 steel chips had the expected high strength, high density and low ductility. The decarburized powder was definitely more suited to this hot forging technique than was Swedish iron powder.

In his work, **Goetzel** also found other iron powders superior to Swedish sponge for hot pressing, although the latter is generally acknowledged to be among the most plastic materials for cold pressing. The powders studied by him included (1) Swedish sponge iron, —100 mesh; (2) electrolytic iron, —100 mesh; and (3) hydrogen-reduced iron, —325 mesh.

The technique used comprised premolding below 10 tons per sq. in., feeding into induction-heated dies at various temperatures between 900 and 2200 deg. F. in a hydrogen atmosphere, and cooling in a special 2-zoned chamber. High pressures (10-50 tons per sq. in.) were used at the lower temperatures, and low pressures ($\frac{1}{2}$-$2\frac{1}{2}$ tons per sq. in.) for the high temperatures. Time periods of pressure application were usually 1 min., with some treatments extended to 10 min.

Fig. 5. Some of the iron parts successfully steam-treated by Lenel's process.

Only in the case of the electrolytic and hydrogen-reduced iron powders could ideal densities be approached below 1475 deg. F., with high pressures. This is notable in view of "the poorer molding qualities of these materials at room temperature in comparison with Swedish sponge." Thus, pure and fine powders seem to be most suitable for hot pressing, and will give superior density, hardness and tensile properties.

Combinations of high temperatures and low pressures or of low temperatures and high pressures both lead to dense materials, but the latter procedure is more practical from the die standpoint. High speed steel dies can be used up to 1475 deg. F. A really satisfactory die metal for temperatures higher than this is still needed.

Under the temperature and pressure conditions studied, extension of time of treatment from 1 to 10 min. increased the density only 10 per cent. **Goetzel's** conclusion from this that temperature and pressure are more important than time in controlling the quality of hot-pressed parts was challenged by **Cordiano** of Charles Hardy, Inc., who reported hot pressing experiments under somewhat different conditions in which time extensions appeared to be a powerful factor in approaching ideal densities.

Discussion failed to bring out any important existing commercial applications of hot pressing in the manufacture of iron parts, although there was general agreement that these would eventually be developed when the process is made more economical, since the method can produce iron parts of unusually good properties.

Steam Treatment of Iron Parts

Cold-pressing and sintering, of course, will always be used for making porous parts. A new method of treating porous iron parts to improve their hardness, elastic properties, corrosion resistance and frictional properties was described by F. V. **Lenel** of Moraine Products Div., General Motors Corp. in "The Steam Treatment of Porous Iron Articles".

The process consists simply of exposing sintered iron articles to steam at 1050-1100 deg. F. The interconnecting-pore network of the sintered part is impregnated with the steam, which reacts with this internal iron surface to form a skeleton of magnetic iron oxide filled with non-reactive iron. Fig. 4 shows the microstructure of an iron part that had been briquetted and sintered from pure iron and then was treated in steam for 1 hr. at 1075 deg. F. The patches of gray magnetic iron oxide can be seen throughout the mass of white ferrite, and, of course, adjacent to the holes or pores.

Best results have been obtained with a mixture of 98 parts of iron powder and 2 parts of graphite, the iron powder being the same decarburized iron-carbon alloy mentioned by **Koehring** in his paper. (However, the general behavior of porous iron articles in steam-treating is the same no matter what kind of iron powder is used.)

The steam-treating apparatus consists simply of a box to which a cover can be bolted; the steam is passed through a pre-

(Continued on page 726)

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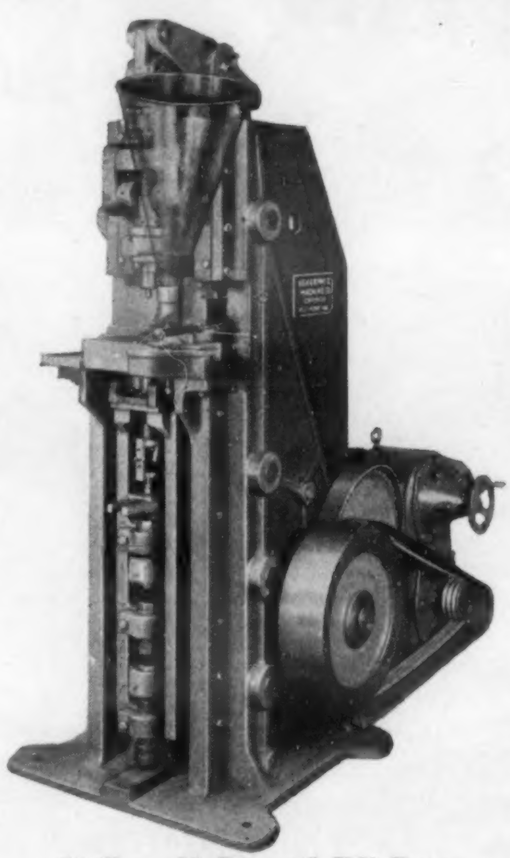

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heating coil before entering the box, and the exit gases, which contain hydrogen and can be burned, leave through another pipe.

The box is filled with the iron parts to be treated and then placed in a furnace at the right temperature. The rate of reaction is rapid when the steam is first admitted, but soon slows down and finally stops. In about 5 min., half of the reaction may be over and in 1 hr. no further increase in weight may be observed.

The amount of oxide formed, as might be expected, is a function of the porosity of the material. For example, in a very porous material that contains 34 per cent of pores by volume, almost 1/3 of the iron is converted to oxide, while in a denser material, with only 14 per cent of voids, less than 5 per cent of the original iron is changed to iron oxide.

The steam treatment raises the hardness in the case of very porous materials from less than 0 Rockwell B to over 100 Rockwell B, and of dense parts from 68 to 92 Rockwell B. The compression yield strength (0.1 per cent offset) of untreated sintered material is 26,000 lbs. per sq. in. and of steam-treated parts 53,000 lbs. per sq. in. The figures for tensile strength of the steam-treated parts are somewhat less than those of the untreated sintered iron articles.

Tests show the new material to be many times more corrosion resistant in industrial atmospheres than ordinary porous iron. When the parts are impregnated with oil after steam treatment corrosive attack can be further slowed. A special property of the oxide-containing iron parts is their very high wear resistance, which has already been utilized for diesel fuel pump vanes.

Some of the practical applications for these steam-treated porous parts are shown in Fig. 5. In two of these—a guide for a metal-cutting saw blade and a drawer roller for stoves, refrigerators, etc.—the hardness and "rigidity" of the material are important. For the diesel fuel pump vanes, just mentioned, the frictional properties of the new material keep the vanes from scoring the vane shoes, particularly during the running-in period.

Stainless Steel Powder

Many of the papers already reviewed were concerned with parts made from iron powder or iron-carbon mixtures or alloys. One ferrous material that is just aching for powder metallurgy application is stainless steel, whose relatively poor machineability is well-known. Attempts to produce a stainless steel powder that will fabricate properly and thus satisfy this need are of great interest, and for that reason the paper by JOHN WULFF of Massachusetts Institute of Technology on "Stainless Steel Powder" was the subject of much discussion.

WULFF's process of making "18 and 8" stainless steel powder is a "corrosion" process in which thin sheets of stainless steel are subjected to specific intergranular corrosion under such conditions that the grain boundaries are dissolved, leaving the individual stainless grains isolated as single-crystal powders. A relatively high carbon "18 and 8" stainless steel containing no stabilizing element is heated in the carbide precipitation range (around 1300 deg. F.)

(Continued on page 728)

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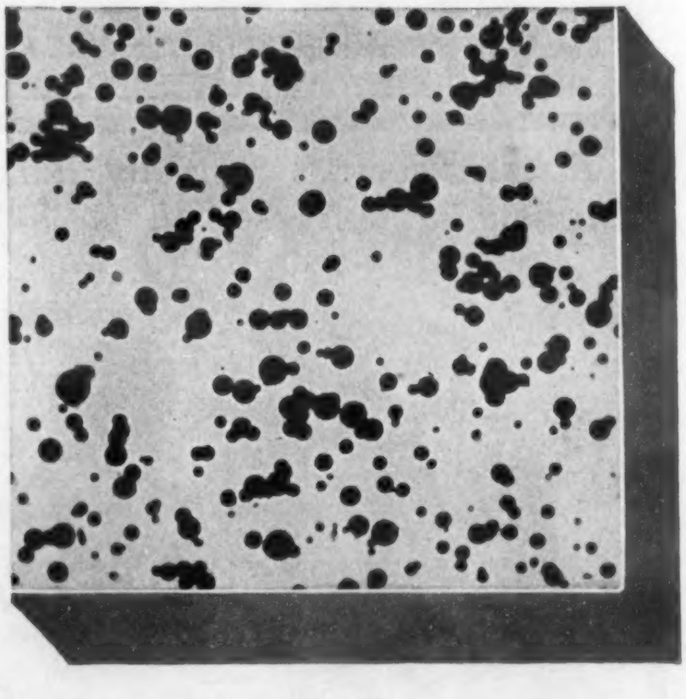

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then immersed in some solution such as acid copper sulphate that preferentially attacks the carbides, precipitated at the grain boundaries.

The brittle corroded sheets are then removed from the solution and very easily disintegrated into powder consisting of single crystals of stainless steel, of a particle size approximately that of the original micro-grains of the solid metal. Previously, cold-worked metal is even more corrodible than annealed material. One incidental advantage of the process is that stainless steel scrap can be used as the raw material. The "corroding" method of preparing metal powders is believed applicable to other metals also.

The molding and sintering properties of the new powder were reported by Wulff to be good. Compacts sintered at 2300 deg. F. and die forged gave theoretical density, tensile strength of 80,000 lbs. per sq. in. and 60 per cent elongation. Sintering must be done in *dry* hydrogen. If finish-machining is necessary, the sintered stainless steel parts were claimed to be more machinable than commercial "free-machining" stainless steel.

Wulff's process implies an advantage in the use of alloy powders for making alloy compacts of this type. However, Hardy of Charles Hardy, Inc., reported that sintered stainless steel parts are being commercially made, particularly in Europe, by synthesizing the alloy from pure metal powders (iron powder, nickel powder and chromium powder). The attainment of ideal composition and structure is assisted by evacuating the powder before pressing and during processing. Stainless steel so made has been drawn into wire 0.003 in. in diameter.

Even with alloy powders, it is necessary to protect the stainless steel briquette against oxidation from oxidizing impurities in the sintering atmosphere. For this purpose, Wulff suggested the admixture of a small amount of titanium hydride powder with the stainless steel powder; Patterson, of Powder Metals and Alloys, Inc., mentioned a similar use for calcium hydride.

Some Processing Factors

A lively discussion of some of the pressing and sintering factors that affect the quality of powder metallurgy products followed an interesting paper by P. E. Wretblad of Fagersta Steel Works, Sweden, on "The Mechanism of Sintering". He defined sintering as the process by which solid bodies are bound by atomic forces, and particularly stressed that sintering, although slow, was entirely possible at surprisingly low temperatures.

The question of "sinterability", previously mentioned in the discussion of Allen's paper, was appropriately re-introduced here, by Kelley of General Electric Co. No practical discussion of sintering, he pointed out, can ignore the effects of type of particle on sintering behavior.

Thus, although sponge iron cannot be *pressed* to the same density as electrolytic iron, after *sintering* it will have consolidated tremendously. Particle *size*, too, is a vital factor in controlling voids.

The cause of cracks in sintered compacts was discussed by Kelley and by

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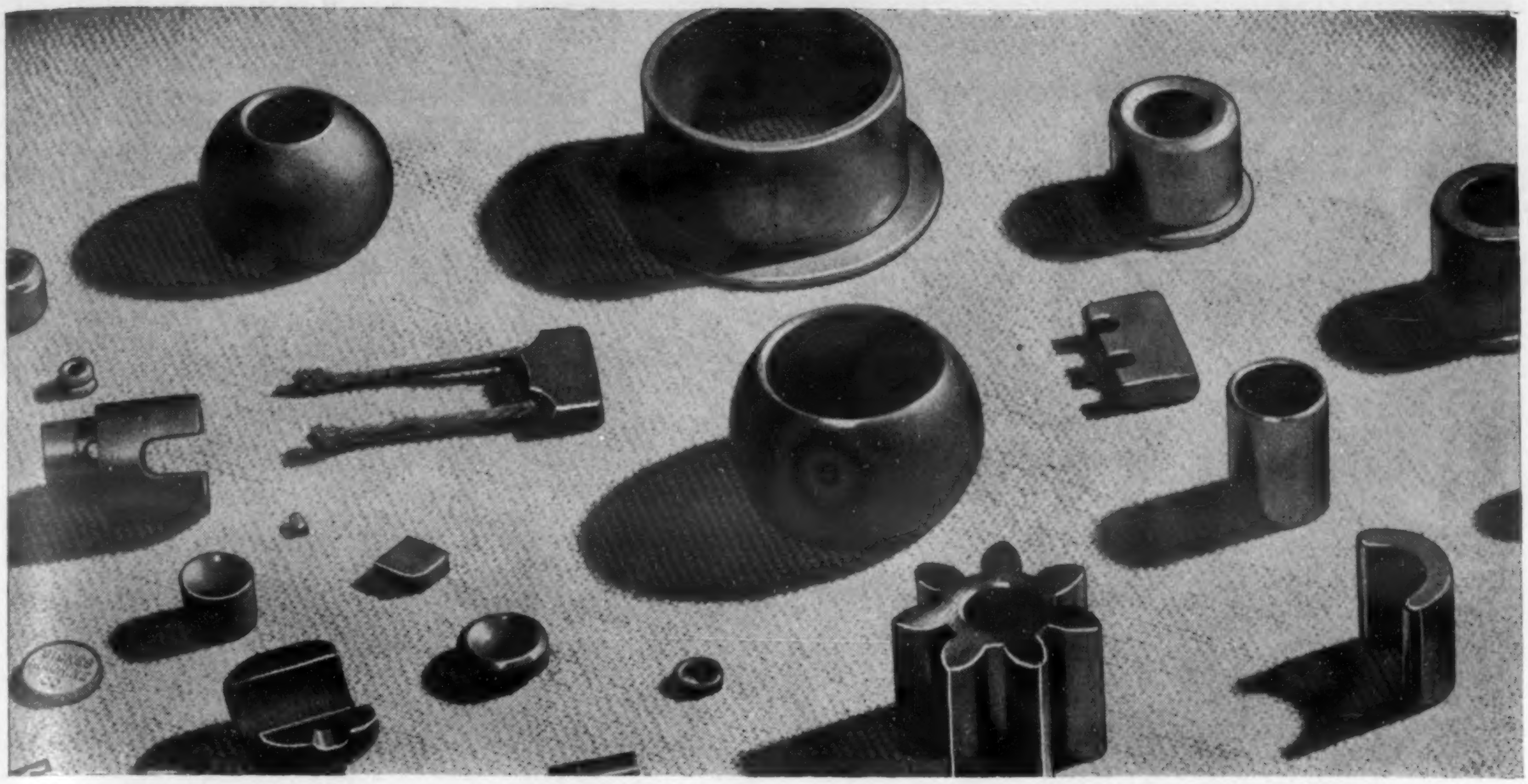

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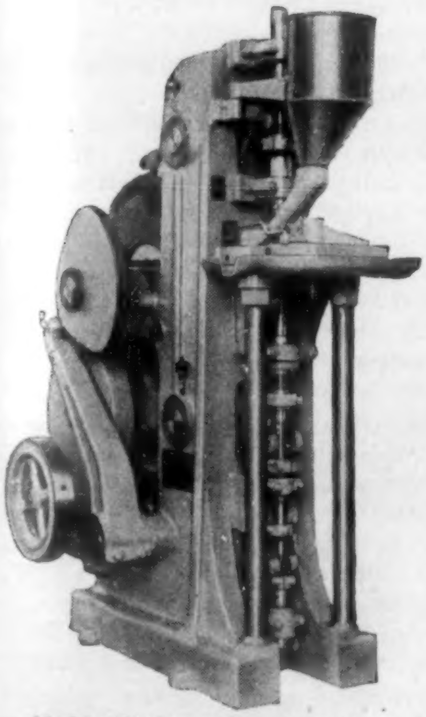

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BAILEY of F. J. Stokes Machine Co. Gases entrapped during pressing were blamed for much of this trouble. Judicious die taper reduces cracks and permits trapped air to escape. However, pressure-expansion of this type is not the sole cause of fractures. Methods suggested for avoiding the familiar X (cone) fractures, for example, were slower pressing and greater die clearance, since such fractures are often caused by the rapid escape of air along the cleavage planes.

Cemented Carbides

Two papers on cemented carbides gave on one hand a broad but intensive picture of the present manufacturing methods, properties and applications of these products of powder metallurgy, and on the other a description of the improvement in grain structure of cemented carbides through the use of finer tungsten particles.

E. W. ENGLE of Carboloy Co., Inc., presented a mountain of data on the properties of cemented tungsten carbides, both plain or mixed with tantalum carbide or titanium carbide, in his paper "Physical and Chemical Properties of Cemented Carbides". Of particular interest were his descriptions of new applications for carbides and of the development of the increasingly used carbide extrusions.

The extrusion process as applied to commercial cemented carbides is capable of producing carbide pieces of greater length than can be made by cold-pressing and sintering, or by hot-pressing. Tubes, rods and strips are now available (some as long as 2 ft. were displayed at the meeting), as well as angles, half-rounds, twist-drills, etc.

At the present time the main applications for cemented carbides are in tools for machining metals and non-metals and in dies for drawing wire, rod, tubing, etc. They are also being used in wear-resistant parts such as gages, thread guides, pump valves, and as the matrix element in which diamonds are held for wheel dressers and core drill bits. Instrument jewel bearings, hot-work shear blades and high speed wood-cutting wheels are among the most recent applications.

ENGEL pointed out that grain size control is important in making the raw material powders, for the structures of the finished composition may be markedly affected thereby. Specific evidence of the critical nature of this behavior was given by M. F. ROGERS of Tungsten Electric Corp. in "Effect of Particle Size Upon the Microstructure of Cemented Tungsten Carbide".

In making tungsten carbide, tungsten and carbon are intimately mixed and fired in hydrogen at a high temperature, the goal being complete conversion to WC, since the carbon-deficient W_2C forms a poor bond with the cobalt binder. Finer tungsten particles present a shorter distance from outside to center, along which the carburizing reaction must proceed. With large particles, this distance is so great that only the outside of the tungsten particle may be entirely converted to WC.

Electron-microscope pictures at 14,000 magnifications of tungsten and tungsten carbide particles were presented. Other

(Continued on page 733)

photomicrographs demonstrated the difference in structure from edge to center of tungsten carbide pieces that were deficient in carbon. The data offered, of course, tied in well with existing knowledge that fine powders make high-strength compacts.

Electrical Contacts

Like cemented carbides, duplex-structure (compound) electrical contacts are among the commercial products that are manufactured only by powder metallurgy methods. A compilation of data on "Compound Contact Metals" and much information on the service conditions they must meet were given by H. H. Hausner & P. W. Blackburn of American Electro Metal Corp.

Electrical contacts must be hard, must not pit (have low material-transfer), and must have good electrical and thermal conductivity. Silver and copper meet the conductivity requirements very well and are often used where the other requirements are not too important. On the other hand, tungsten and molybdenum with their high hardness and low material-transfer are employed where these requirements overbalance the conductivity needs.

The ideal material for most contact purposes would be one with the conductivity of silver or copper and the low material-transfer of tungsten or molybdenum. Alloying will not achieve this, but powder metallurgy methods do achieve compound metals that combine these essential qualities in one duplex material.

The choice and proportion of hard metal and of conductive metal depend on the service. For example, in oil circuit breakers molybdenum-silver contacts are used; in air circuit breakers, the oxidation factor impels the use of tungsten-silver. For contacts operating at high currents, about 100,000 amps., silver-nickel-tungsten contacts, with a density over 17 and hardness of 260-300 Brinell, are used.

The effect of processing factors—pressure, sintering temperatures, type of powder used, etc.—on density, hardness, strength and conductivity was examined. For example, changes in hardness of 16-18 per cent in an 82 tungsten, 18 copper mixture resulted from variations in particle size and type (reduced vs. electrolytic) of copper powder. Fine electrolytic copper particles gave the highest hardness, with coarse electrolytic just behind.

The Fundamentals

The quiet attack on the fundamental and unsolved problems of powder metallurgy continues also. F. N. Rhines of Carnegie Institute of Technology discussed "Homogenization of Sintered Copper-Nickel Alloys". His work was with highly pure copper and nickel powders and permitted him to formulate certain concepts susceptible of mathematical expression.

The situation for fastest alloying by diffusion of such powder mixtures seems to be a combination of large particles of the major constituent with small particles of the minor. For practical purposes, impurities have a profound effect on the rate of sintering and alloying only when they surround the metal particles as films.

A method of measuring the surface area of powder masses by "adsorption isotherms" was described by P. H. Emmet of Johns Hopkins University in a paper "Adsorption Isotherms of Fine Powders". Best used for particles 20 microns or smaller, the method gives *surface* area, but not necessarily particle size (unless the actual porosity of the typical particle is known).

One interesting sidelight on Emmet's work was his observation that even down at liquid air temperature, oxygen immediately formed a 5-iron-atom layer of oxide on freshly reduced iron surfaces, thus demonstrating the practical difficulty of getting pure iron surfaces at room temperatures when contact with oxygen is not scrupulously avoided.

L'Envoi

The conference this year was refreshing in the extra time for discussion available, as compared with the shortened forums of last year's meeting. And whatever the opinion of the quality of the papers presented, there was general agreement that a conclave of this type every year is highly beneficial to this field, if for no other reason than that it permits the people in the field, normally widely separated geographically, to see each other in one place and to discuss, often privately, countless matters that can't even be put into correspondence.

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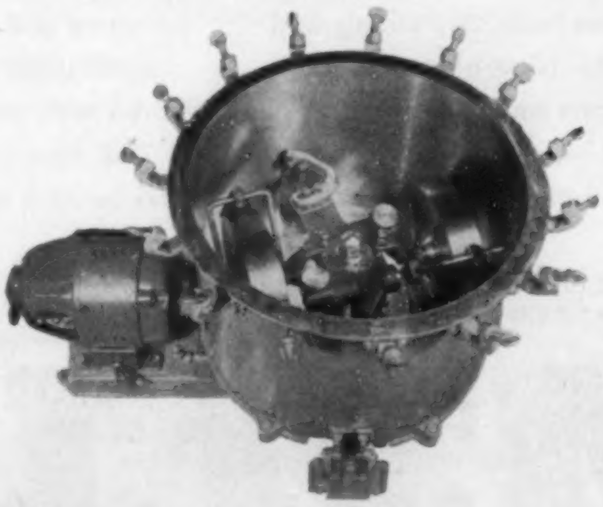

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Illustrated above are a few typical powder metallurgy parts made from materials mixed and blended in a Simpson Intensive Mixer. These modern machines are built in a wide range of sizes, available with electric heating elements or steam jacketed, to meet any production requirement. At the left is a Laboratory size machine, with stainless steel pan to guard against contamination and with electric heating elements for temperature control.

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METALLURGICAL ENGINEERING news

Equipment
Finishes
Materials
Methods
Processes
Products

Alloys
Applications
Designs
People
Plants
Societies

Defense Perspectives

Looking at the defense news for October in perspective, several salient points stand forth. The steel expansion program managed to get beyond the talking and paper stage and experienced some concrete action.

The OPM tracked down and punished its first priority violator and hinted that more would follow. Copper commanded the spotlight when SPAB decided that there was a shortage and banned its non-defense uses, while aluminum was just edged into the light with announcements of new plant expansions and with the revelation that large piles of low-grade "orphan" aluminum were accumulating. Conservation and metal substitutes continued receiving well-needed attention, and civilian supply received more drastic cuts.

Steel Expansion

When steel production is expanded, the five factors, which are inseparably connected with steel-making, must all be expanded together, otherwise the program will fail. These five essential considerations are: pig iron, scrap, coal and coke, manganese, and steel plant facilities.

After announcing that the steel production capacity would be expanded at least 10,000,000 tons, the government last month began to execute the plans for expansion of all but one of the five essentials to steel-making.

Republic Steel Corp. was given grants to expand their pig iron production 1,750,000 net tons, to build 276 additional coke ovens, and to increase their alloy steel output 318,000 tons. Inland Steel Co. announced an expansion in its pig iron production of 900,000 net tons; Bethlehem Steel Corp. was granted $55,777,000 to increase its output of pig iron, coke, open hearth steel ingots and plates.

For strategic reasons, steps were taken to make the West Coast largely independent of Eastern steel plants. A 500,000-ton steel plate mill and a plant capable of turning out 30,000 tons of steel casting at Pittsburg, Calif., will be constructed. The pig iron for these mills will be manufactured in new blast furnaces to be constructed in Utah.

Getting the necessary scrap for the steel expansion presents the toughest job, for even to fulfill the scrap needs under the steel industry's present schedule, annual collections must rise 3.5 million tons. One step towards alleviating the shortage came when full priority control was placed on iron and steel scrap on Oct. 9th. Beginning Nov. 15th, producers, brokers and consumers will have to make complete reports on their dealings with scrap. It is expected that on the basis of these reports, a general policy for the distribution of scrap will be developed.

But the government and the steel industry have resigned themselves to the fact that scrap cannot be had in sufficient quantities to fully satisfy steel production needs, and that to make up for the scrap deficiency pig iron resources must be further tapped.

Very nearly all the manganese, which is so vital to steel-making, is imported from other countries. Fortunately, the war has cut off only one source of supply, Russia, so far. There is very little the government can do towards increasing or insuring the supply of manganese except to keep open the sea lanes over which it must travel. At the present time, the Bureau of Mines is developing a domestic electrolytic manganese. But this process is still in the small-plant stage and a number of years may be required to obtain facilities for producing the metal in appreciable quantities.

It remains to be seen whether or not the expansion of each integral part of steel-making is being planned and timed wisely. This is certain—if any one of them gets behind, steel production in general will also lag.

Non-Ferrous Metals

Copper was added to that rapidly growing, select list of scarce metals last month when SPAB issued an order banning its use for non-defense items after Jan. 1st, 1941. It was understood that October's requirements would fall short by at least 6,000 tons.

The shortage of copper prompted the Priorities Division to grant priority assistance to Latin-American copper mines, which are producing large quantities of this metal. This assistance will enable the mines to obtain maintenance materials and operating supplies more rapidly. A priority rating of A-10 was also given to 150 domestic refiners of copper scrap and copper-base alloy.

Two major aluminum plant expansions were announced last month, including one for a 60,000,000 lb. output to be operated by Reynolds Metals Co. and another, which is to be built and operated by the Aluminum Co. of America, to have an annual capacity of 150,000,000 lbs.

While aluminum expansions got underway, there was news that huge piles of low-grade "orphan" aluminum were accumulating in the plants of aluminum producers, fabricators and dealers. This variety of aluminum, which is below the government's rigid specifications, could well be used as the deoxidizing agent in steel-making; or, if the priority restrictions were lifted, it might be applied to the manufacture of non-defense products.

The production of magnesium is to be upped to around 56,000 tons per yr. beginning in 1942, according to reliable reports. Last year our production was 6,000 tons.

Conservation and Substitutes

The middle of last month found a new centralized organization established, known as the Bureau of Industrial Conservation, and organized to coordinate all the conservation efforts formerly sponsored by several groups. The purpose of the merger is to assure the saving and salvage of every possible pound of usable material, which had previously been wasted.

Civilian needs were slashed from all sides. The mechanical refrigerator production was cut 43.2% for the last 5 months of this year, and hints were preva-

(Continued on page 738)

FUSE FIRE AND

TO GET REFRACTORIES THAT STAND

Fused at white heat, fashioned to baffle time, are the raw materials of Norton refractory products.

But no less important than bauxite, magnesite, coke, or purest silica sand, is the spark of *research*, Norton Ingredient Number One, which first fits the refractory material to the job and then makes it *stay there.*

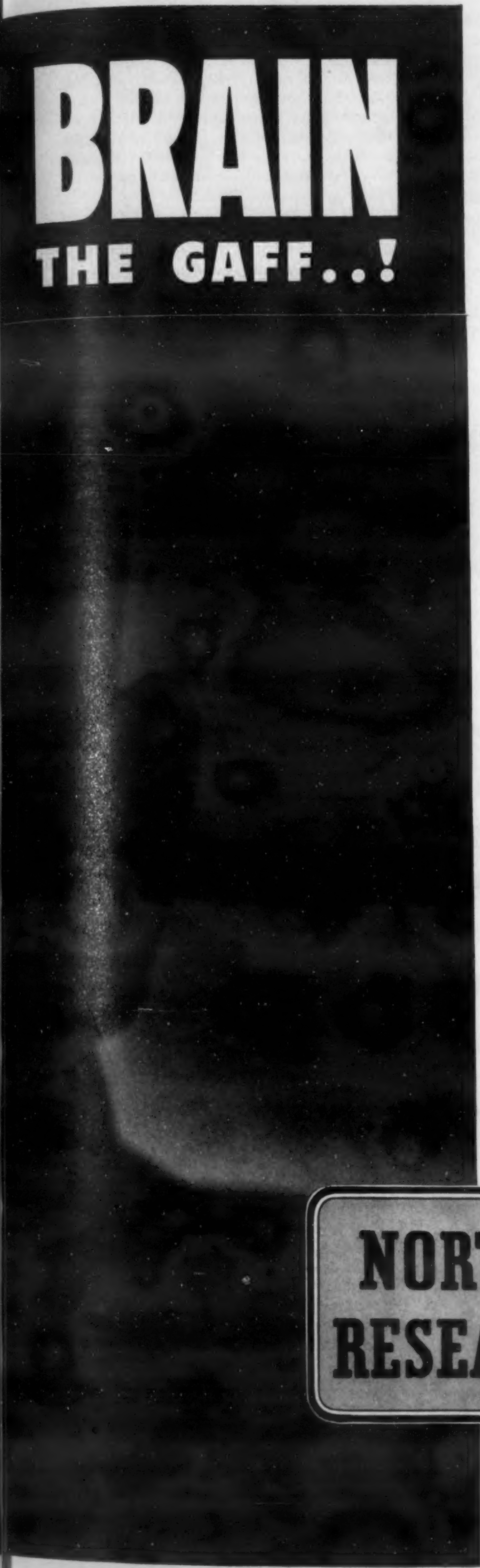
Norton engineers, specializing exclusively in electric-furnace-fused refractories, know that it takes the fire of practical imagination, the spark of research to fuse many variables into a refractory product that will fill your particular requirements.

Do you want porosity—plus resistance to crumbling? Strength and chemical inertness? A contact for melts that is non-oxidizing? Permeability without loss of strength?

Whatever your problem, when you buy a Norton refractory product, you get the single-minded attention of Norton's scientific and sales engineering staffs. You get a dynamic response to *your* problem, based on years of *specific* research for Norton customers.

IMAGES OF HEATED STEEL SEEN THROUGH LASTING TUBES

Costly, special alloy "sighting tubes" to observe and control furnace temperatures, frequently had to be replaced owing to oxidation and scaling. Norton engineers, working with a leading instrument manufacturer, devised silicon carbide CRYSTOLON tubes which filled the bill. Result: months of satisfactory service, longer tube life, lower tube costs.



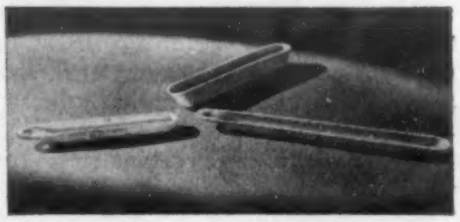
FIRING LINE NEWS

Crystolon Hearth Plates Make Your Furnace Bigger without Changing Its Size!

Bigger production capacity for your furnaces is possible when you switch to CRYSTOLON hearth plates, thinner because they are made of industry's strongest refractory material, silicon carbide. Naturally, the silicon carbide base means also that constant abrasion by heavy metal shapes results in very slow wear. Abrasion is the meat of CRYSTOLON products. Hence — amazingly long life, lower maintenance costs, and best of all, prevention of shut-downs for repairs. Even *this* doesn't tell you all the dividends you get from CRYSTOLON hearth plates. Their unsurpassed, rarely-matched heat conductivity cuts your fuel bills, transmits B.T.U.'s from fuel to metal quicker, with less waste.

Slag Meets Its Master in CRYSTOLON Slag Hole Blocks for Malleable Iron

Bonded densely together, the tiny silicon carbide crystals of CRYSTOLON slag hole blocks give a smooth, non-permeable surface that baffles slag seeking to take hold. Whatever the slag action, either by corrosion or erosion, the resistance of these CRYSTOLON blocks is astonishing. As for the heat of the slags, CRYSTOLON refractories thrive at temperatures up to 1650° without spalling or softening.



Combustion Boats with 9 Lives for Carbon Determinations

By lining a Norton Combustion Boat with R.R. ALUNDUM Grain (thus protecting it from softened metal, oxides and slag), you can use it over and over in carbon determinations. The great refractoriness of ALUNDUM material (up to 2050°C.) protects your boat from being shattered by heat, thus saving boat replacements and preventing loss of sample. Boats made of a special mix (coarse RA 98) carried in stock for determination of graphitic carbon in pig iron. Where steel analyses are performed constantly, special "Heavy-Duty" Combustion Boats are indicated. Zircon Combustion Boats also carried. To intercept spattering metallic oxide during combustion — ALUNDUM Boat Shields (thin walled tubes) lengthen combustion tube life.

NORTON RESEARCH

Ingredient Number One in Longer Lived Refractory Products –

Refractory Shapes and Cements of CRYSTOLON (silicon carbide), ALUNDUM (fused alumina), and Fused Magnesia Grains

NORTON COMPANY, WORCESTER, MASS.

Defense Perspectives

(Continued from page 735)

lent that next year's reduction would be even greater. The program is designed to save 175,000 tons of steel a year and effect substantial savings in other metals such as aluminum, brass, chromium, copper, nickel, iron, tin and zinc.

Passenger automobile production was whittled down some more when it was announced that the output for January would be 51% below the same month of 1941. Non-essential housing felt the effects of the defense squeeze when construction of non-defense projects was banned. Although a saving of around 3,000,000 tons of steel was expected, about 1,200,000 tons of it will probably be used in defense construction. The average weight of bicycles was ordered cut at least 10% and decorations of chrome, copper and nickel are to be eliminated.

What can be done in the way of saving vital metals was very well illustrated in a report on proposed savings in telephones by the Bell Telephone Co. They plan to reduce the yearly rate of use of aluminum by 1,670,000 lbs., nickel by 238,000 lbs., and zinc by 3,380,000 lbs. Zinc has been used in the past for housing the combined telephone set, but already 34% of the sets in manufacture are of a plastic composition.

Plastics as a substitute continue in popularity. The 1941 output will be some 200% ahead of 1940. Fourteen experimental gliders, including 4 large troop carrying ships, of a newly developed, wood-impregnated plastic, were ordered by the Navy.

The Axe Falls

The OPM last month finally finished sharpening its axe and began to wield it. The cutting edge first descended upon an aluminum foundry in Chicago, who reportedly violated priority orders by diverting scarce aluminum from vital defense production to non-essential applications.

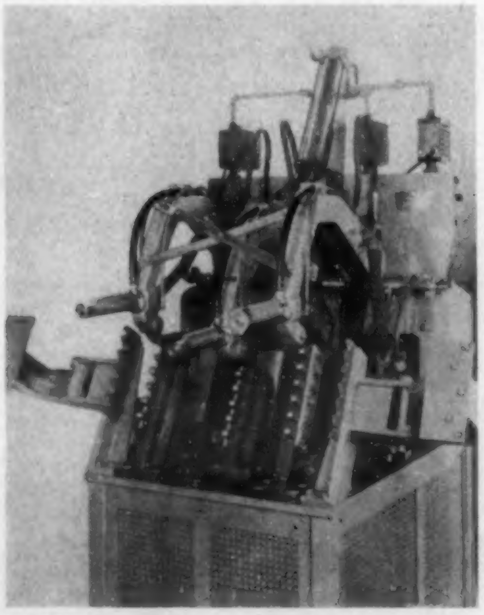
The chief charge against the company was that it manufactured and shipped 41,449 lbs. of aluminum products, including juke box castings, coin machines and camera parts, in violation of priority orders. Because of this alleged non-compliance, the company has been ordered to shut down all aluminum operations, except defense orders, until Mar. 31st, 1942.

This first drastic punitive action followed on the heels of a comprehensive nationwide priority-violations check in which 275 Federal employees are being used. To begin with, 1,800 aluminum foundries are being checked and as soon as that job is finished, other fields will be investigated. Priorities Director Nelson said that this was just the beginning, and to protect the majority of business men who were complying with the priority regulations, everything possible would be done to catch and punish the outlaws. From that warning, it looks as thought some others besides turkeys may feel the sharpened axe before Thanksgiving.

Resistance Welding

Welding guns that locate themselves automatically for spot-weld assembling of units built up of a number of parts are features of a welding fixture and gun assembly recently developed for the assembly welding of grilles for a low-priced 1942 model automobile.

Built by *Progressive Welder Co.*, Detroit, the unit is provided with 3 guns mounted on arms projecting from a slide. The operation required the performing of 17 welds in the assembly of the unit. The fixture was so designed that the welds could be performed in groups of 3 in 5 different positions of the welding guns, while in a sixth position, only 2 of the guns are actuated.



This was accomplished by providing the slide carrying the guns with an automatic indexing device. To assemble the grille, it is necessary only to locate the parts in the fixture over the fixed electrodes, clamp them with the 2 clamps provided at left and right of the fixture, and press a button.

The slide then moves down to the first position, the points of the guns move in against the work, and the weld is started automatically. The points then move out, and the slide carries the guns to the next welding position. The same cycle is gone through, and the slide moves the guns to a third position.

After all welds have been completed, the slide moves the guns to the starting position and stops, permitting the removal of the assembled grilles and inserting a new set of parts for assembly welding.

With two such welding fixtures, it is possible for one to be loaded while the other is going through its assembly welding cycle.

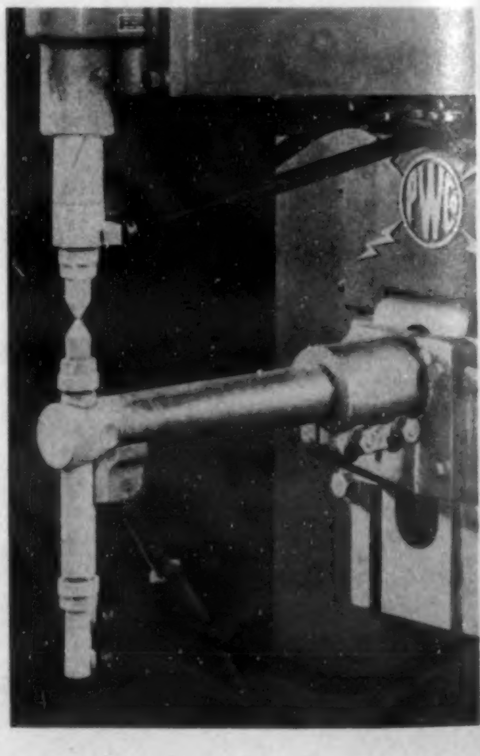
Refrigerated Welding

A refrigerating unit for use with resistance welding machines to reduce the temperature of the welding points has been announced by *Progressive Welder Co.*, Detroit.

Designed to increase productivity of resistance welding equipment in welding aluminum and stainless steel, the unit is believed to be the first of its kind commercially available.

The unit makes possible continuous welding of 4 to 10 times as many spots in aluminum, it is claimed, without requiring point dressing. When used in combination with a spot welding machine, the unit reduces electrode temperature to a point where the electrodes will be continuously covered with frost regardless of the high heat necessary to produce a weld.

This reduction in temperature, it has been pointed out, has so increased point life that 10-min. runs at 100 welds per min. without point dressing are possible with the use of the new refrigerating unit in conjunction with a 3-phase aluminum welder.



Primary function of the refrigeration is to keep the welding point cool at the point of contact. In resistance welding, heat is generated at 3 primary resistance points, these points being: (1) at the point of contact between the pieces being welded together, (2) at the point of contact between the "upper" piece and upper electrode, and (3) between the "lower" piece and the lower electrode.

Only the first, of course, is desirable, the other two tending to soften and permit deformation of the electrode tip as well as producing pick-up, by alloying of the tip with the material being welded.

Experimental production to date indicates a complete elimination of pick-up when the refrigerating unit is used. Retention of tip shape by preventing softening is also reflected in the maintenance of higher current density at the weld.

The unit can also be used for welding other types of material besides aluminum and stainless, and may also be applied to the cooling of industrial coolants, cutting oils, etc.

Resistance Welding Control

A new capacitor-discharge control specially designed for use with stored-energy type resistance-welding machines has been announced by *General Electric Co.,* Schenectady, N. Y. Stored-energy resistance welding is especially suitable for welding low-resistance alloys, such as aluminum used in aircraft fabrication.

In the capacitor-discharge method of resistance welding, electric energy is stored in the capacitors of the control by a charging circuit, and then rapidly released into the welding transformer, the resulting current producing the weld. The charging circuit then recharges the capacitors, and the operation is repeated.

The control cabinet contains up to 22 capacitors, any number of which can be used at one time. Two special tap switches select the number of capacitors desired in one-unit steps, each of 120 microfarads. By adjusting the voltage output of the control, and by selecting the number of capacitors, flexibility in welding is assured.

A special circuit, which prevents operation of the welding machine if the capacitor voltage is more than 3% below its preselected value, reduces the possibility of insufficient energy to produce good welds. The charging circuit quickly and automatically charges the capacitors, to the preselected voltage regardless of the number used, thus allowing fast welding speed.

Safety devices with this control include a remotely controlled discharge contactor, a manually operated 3-phase circuit breaker protecting the anode transformer in case of a short circuit, and interlock cabinet doors, which, when open, automatically discharge the capacitors.

A line of resistance welding heat controls has been designed by *Weltronic Corp.,* Detroit, to cover a variety of applications, including single-weld operations, using either guns or pedestal-type welders, pulsation welding, and multi-spot welding.

All the heat controls are of the electronic type, which provides an infinitely variable adjustment of current value. By using such heat controls, auto-transformers may be omitted in the welding circuit.

With electronic heat control, the electronic type of contactors must be used in the welding equipment circuit.

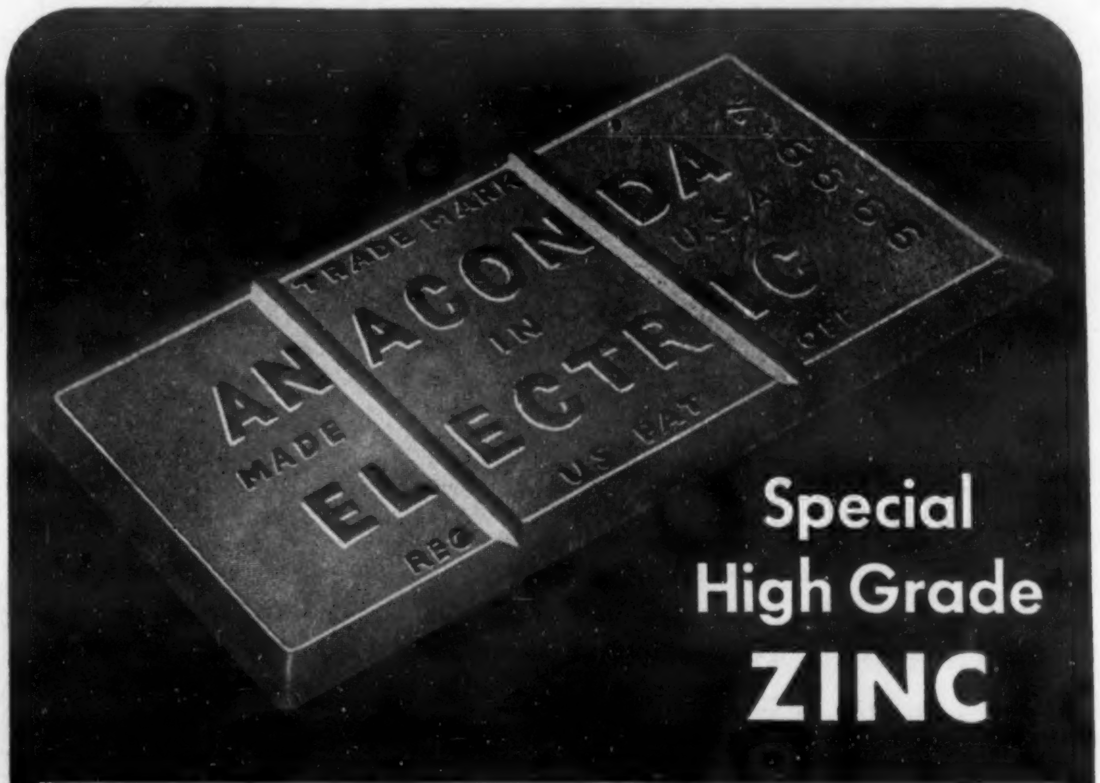
Personals

Otto W. Winter has assumed the duties of vice-president in charge of manufacturing of the Republic Drill & Tool Co., Chicago. He was formerly with Columbus McKinnon Chain Corp., Tonawanda, N. Y. . . . Meehanite Metal Corp., Pittsburgh, has appointed as director of research *Wm. F. Lamoreaux,* who for many years was employed by Ducktown Chemical & Iron Co., Isabella, Tenn.

Battelle Memorial Institute, Columbus, Ohio, has recently made three additions to its staff: *Charles J. Slunder* has been assigned to the division of electrochemical research; *Philip C. Rosenthal* will direct investigations in metallurgy; and *Carl L. Wallfred* has been named to the technical staff of the division of process metallurgy research.

Leo A. Behrendt has joined the Crucible Div. of the Joseph Dixon Crucible Co., Jersey City, N. J. . . . *Wm. T. Bryon,* formerly in the Technical Div., E. I. duPont de Nemours & Co., Inc., is now with Duriron Company, Dayton, Ohio, as metallurgical engineer.

Victor H. Lawrence, who was formerly with Alan Wood Steel Co., Conshohocken, Pa., has been appointed assistant to the president of Otis Steel Co., Cleveland, Ohio.



Guaranteed 99.99+% Pure

WHEN you choose Anaconda Electric for the base of Zinc die castings, you are certain of obtaining uniform, dependable metal. For every slab of Anaconda Electric Zinc is electrolytically refined and guaranteed 99.99+% pure.

Anaconda Electric Zinc is supplied in 50 lb. slabs clearly marked "Anaconda Electric 99.99+%." Whenever you use this well-known brand, whether in small quantities or carload lots, you may be sure that *every slab will test 99.99+% pure.*

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ANACONDA
from mine to consumer

ANACONDA SALES COMPANY
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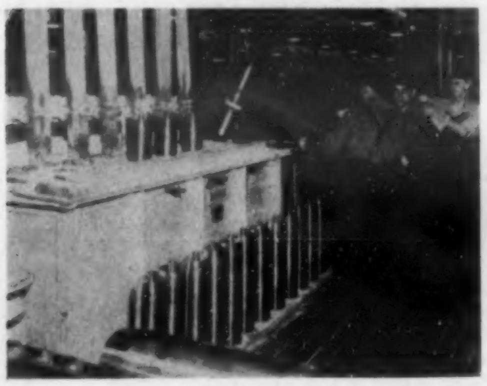
Subsidiary of Anaconda Copper Mining Company

Salt Baths for Heating Shells

Shell forgings at the rate of 40 an hr. are being heated for nosing in each one of a large battery of elecric salt bath furnaces at the Willys-Overland Toledo plant. One of the salt baths, made by *Ajax Electric Co.,* Philadelphia, is shown in the accompanying illustration.

This method of heating makes possible forging at temperatures 500 deg. F. lower than those usually considered necessary for this work. The low forging temperature is said to eliminate most of the rejects caused by eccentricity, wrinkling, linear distortion and scale.



The application of mass production technique with no waste motion, and the automatic temperature control within close limits avoids under- or over-heating vital portions of the shell.

Shells are actually heated for a length of but 9 in., with sharp, visible demarcation between the hot and relatively cold portions. They are then inserted in the forging press, which squeezes the hot nose shut and produces the familiar projectile shape.

The slight salt film clinging to the shell is found to aid the operation, and is not removed by the usual water rinse until the forging is completed.

Plants and Slants

Turbo-superchargers are being turned out by the hundreds each week by *General Electric Co.'s* plant in Schenectady, N. Y. Two additional plants for the exclusive manufacture of turbo-superchargers are being built, which will add more than 500,000 sq. ft. of additional floor space.

Cold Metal Process Co., Youngstown, Ohio, has announced the organization of a subsidiary company to take over the manufacturing operations. The new organization will be known as Cold Metal Products Co.

The construction of a new alkali plant in Ambler, Pa., by *American Chemical Paint Co.,* is rapidly being completed. The activities of the Tidewater Div. will be moved to this new plant, where all alkalies and cleaning compounds will be manufactured.

A contract that involves the construction of two blast furnaces having an estimated pig iron capacity of 900,000 tons per yr., has been signed by *Inland Steel Co.,* Chicago, with the Defense Plant Corp.

Ampco Metal, Inc., Milwaukee, Wis., has announced that plans are in progress for constructing additions to their machine and forge shops.

A 100% increase in the company's output of lighting equipment for the nation's air defense and factory production lines has been assured with the completion of three new buildings at *Westinghouse Elec. & Mfg. Co.'s* plant in Cleveland.

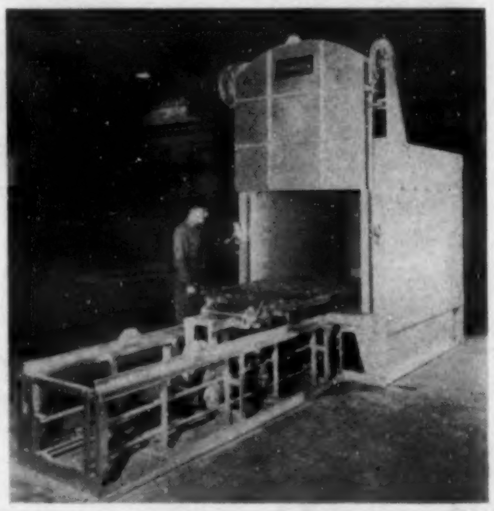
Methods for obtaining coarse-flake graphite, which is essential to the manufacture of crucibles used in making brass, other copper alloy castings and special steel castings, are being experimented with by the *Bureau of Mines*. Practical commercial tests are now under way to treat Alabama graphite ores, and if successful, this source will eliminate the use of the Vichy-owned island of Madagascar as a source of supply.

The R. Y. Ferner Co., Boston, Mass., has been appointed the exclusive agents by Cooke, Troughton & Simms, Ltd., for high precision optical measuring instruments and similar items.

Ironton Fire Brick Co., Ironton, Ohio, has changed the name of their siliceous ramming refractory from "Ironton Superline" to "Ironton Caro-Line." This revision, the company says, better suggests North Carolina, the state from which the refractory mineral used in this product is obtained.

Roller Grid for Heat Treating Furnaces

An automatic roller grid has been developed for use with the forced convection box type furnace by the *Lindberg Engineering Co.,* Chicago.



The roller grid on this type of installation, which has particular use in the heat treatment of aluminum alloy aircraft parts, is powered by an air cylinder that pushes a carriage to the work chamber where the roller grid is automatically engaged. The carriage then quickly pulls the roller grid along the tracks from the work chamber out into the open where the work is easily accessible, and can be rapidly removed for quenching.

The grid is reloaded, and automatically moved back into the work chamber where the carriage disengages the roller grid, and moves back to allow the hand-controlled air-operated vertical lift door to lower into place.

Heating is accomplished with a high velocity fan that forces large volumes of air under pressure and at velocities of around 2 miles a minute over the heating elements and through all parts of the work chamber.

The heating elements consist of coiled nickel-chromium wire, and are situated with the fan in a separate chamber away from the work chamber, but within the furnace. Elements are situated in the separate chamber for 2 reasons; first—to permit quick and easy replacement, and second—to prevent radiation from heat source to charge, which would cause local overheating.

Iron Powders

Work is being carried on in developing and perfecting equipment for the production of electrolytic iron powder and melting stock at the Mellon Institute of Industrial Research under a multiple fellowship of *Plastic Metals, Inc.,* Johnstown, Pa.

The two powder products that are being studied are electrolytically produced iron powder, containing as high as 99.95% iron and sponge iron powder.

Owing to its purity, the electrolytic iron powder is said to possess unusual electrical properties. In powder form it can be utilized in the fabrication of magnets, various types of radio cores, and other electrical appliances. In the form of sheets or plates, this iron has proved useful as melting stock in the preparation of spectroscopic standards and high-quality ferrous alloys, which demand extremely close control of all constituent elements.

The sponge iron powder has been found suitable for compacting metal parts where powder having the purity of electrolytic iron powder is not essential.

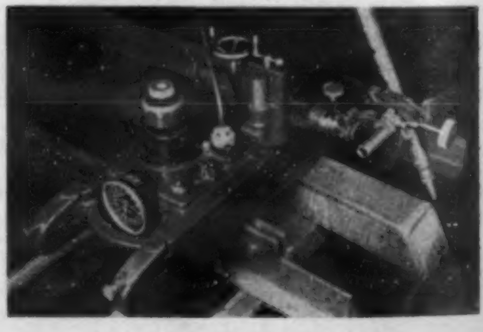
Stainless-Clad Steel Tank Car

What is believed to be the first tank car in which the tank is constructed entirely of welded stainless-clad steel, has just been completed by General American Transportation Corp. at their Sharon, Pa. plant. The tank required 15,000 lbs. of stainless-clad steel, supplied by the *Jessop Steel Co.,* Washington, Pa.

Use of stainless-clad steel in this equipment prevents contamination of the contents of the tank, as the stainless cladding on the inside of the tank successfully resists the chemical attack that would have taken place had ordinary steel been used.

Machine Flame Cutting

A new type torch holder for use with cutting torches has been introduced by *Air Reduction Sales Co.,* New York.



The new holder is shown in the accompanying photograph being used to bevel cut a billet. Any desired angle of cut is made possible by the new type holder. A circular knurled knob permits angular adjustment, as shown on the scale.

Regalvanized Welds

A new patented process for regalvanizing after the welding of galvanized metal parts has recently been announced by *Galv-Weld, Inc.*, Dayton, Ohio.

The process is applicable to all types of welding, including arc, gas and spot welding. The welds are made in the usual manner, using standard arc or gas welding rods.

While the weld is still red hot, it is brushed briskly with a wire brush to remove slag and scale. A galvanizing material in bar form is then held against the weld while the latter is still hot enough to melt it. The weld is again wire brushed while the galvanizing material is in a liquid state so as to spread it evenly over the entire weld.

The welded joint after using this process is said to be thoroughly rust-proof. Welded products can be manufactured from galvanized sheets or shape, eliminating entirely the dipping of the finished product to rust-proof it.

An additional feature claimed for the new process is that it permits the painting or enameling of a welded joint without danger of sweating.

Meetings and Expositions

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, annual meeting. New York, N. Y. Dec. 1-5, 1941.

EXPOSITION OF CHEMICAL INDUSTRIES. New York, N. Y. Dec. 1-6, 1941.

WANTED TO BUY

METALLOGRAPHIC MICROSCOPE, INVERTED TYPE. Late model Zeiss or Leitz preferred. State make, condition, optical equipment and price. School of Mines, University of North Dakota, Grand Forks, N. Dak.

FREE SERVICE DEPARTMENT

Replies to box numbers should be addressed care of METALS AND ALLOYS, *330 W. 42nd. St., New York.*

POSITION WANTED: Tool steel metallurgist, 30 years old, married. Five years' metallurgical experience. Special knowledge in heat treatment and fabrication of tools. Considerable experience with molybdenum high speed steels. Knowledge of induction hardening. Competent in supervision of physical testings laboratory, research or production. Experienced Metallographer. Prefer New England region. Box MA-29.

HELP WANTED: Metallurgist—New York State manufacturer wants a man thoroughly trained in metallurgical engineering for a permanent position. Prefer man who is familiar with both ferrous and non-ferrous materials. Experience in carburizing and heat-treating is essential. State full experience and salary expected in first letter. Correspondence will be kept confidential. Box MA-30.

Finishing Control Systems

Two new systems of control—one for the temperature control for pickling tanks and the other for control in sheet tinning pots—have been recently developed by *Brown Instrument Co.*, Philadelphia.

The temperature control system for pickling tanks was designed to overcome the difficulties arising from corrosive conditions in the pickling room and to lend itself to ease of manipulation as well as accuracy in operation.

Some of the advantages of this system are said to be greater uniformity of pickling, shortening of pickling time, saving materially on steam cost, saving of acid, and reduction of injuries to men and machinery.

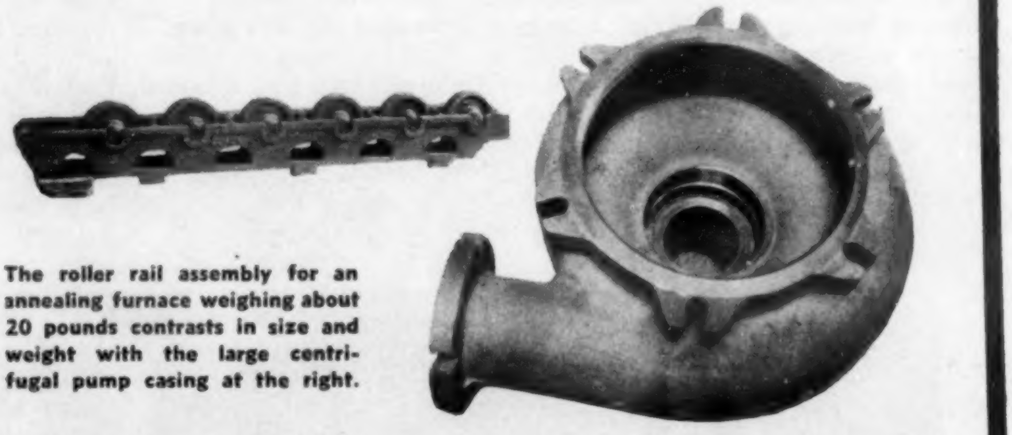
The tin bath control system is made up of a thermocouple in a seamless steel protecting tube, immersed in the tin bath, a single record proportioning control potentiometer, a control relay and a motor and valve.

The close control of temperature of the tin bath assures a more even quality of tin plate, close control of depth of coating, a more constant production, a longer life of tinning pot, immediate response to changes, and a reduction of tin loss.

DURALOY

20 years' Experience in Producing Chrome-Iron and Chrome-Nickel Alloys

10 years' Experience in Producing Centrifugal High Alloy Castings



The roller rail assembly for an annealing furnace weighing about 20 pounds contrasts in size and weight with the large centrifugal pump casing at the right.

And this experience is not surpassed by that of any others in this country!

Yes, we have the experience to select proper alloying analyses to meet problems of temperature, corrosion and abrasion. We also have as modern a foundry as can be found anywhere with every facility for turning out sound castings, finished to any degree desired—and ranging in size from that of a watch up to several tons.

THE DURALOY COMPANY

Office and Plant: Scottdale, Pa.
Eastern Office: 12 East 41st St., New York, N. Y.

DETROIT: The Duraloy Co. of Detroit
LOS ANGELES: Great Western Steel Company
SCRANTON, PA.: Coffin & Smith
Metal Goods Corporation: St. Louis • Houston • Dallas • Tulsa • New Orleans

11-DU-1

METALLURGICAL ENGINEERING

shop notes

Magnetic Sorting of Metal Parts

by C. S. Williams
Westinghouse Electric & Mfg. Co.

Many engineers may be interested in an improved apparatus that can be used to identify and sort small steel or iron parts that differ, among other things, in their effects on a magnetic field.

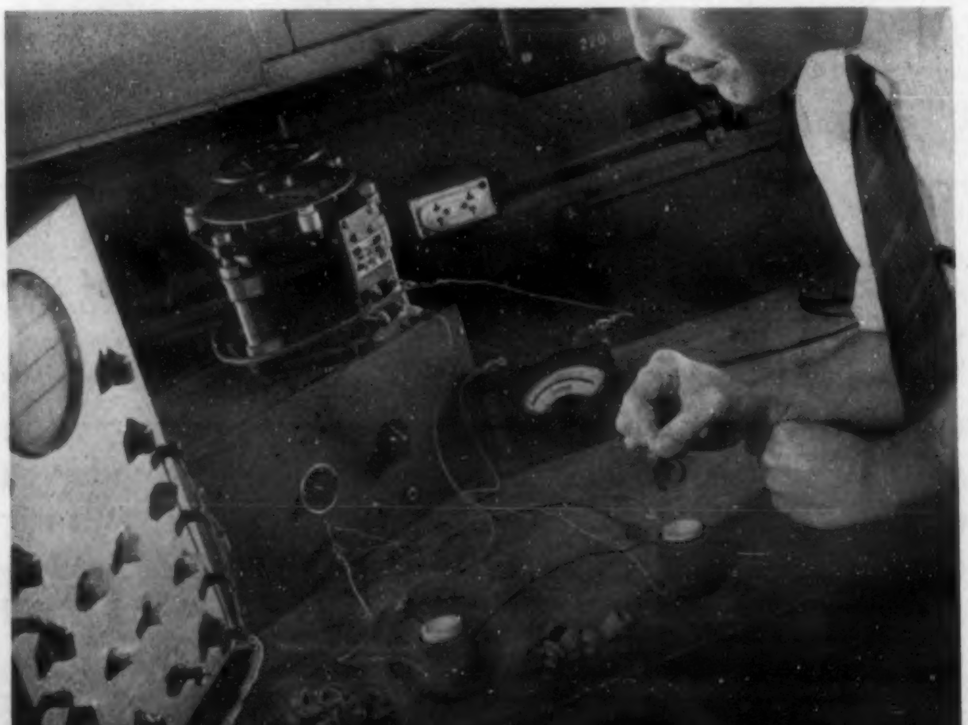
The device was originally assembled in one afternoon in our laboratories for the purpose of "unscrambling" a mixture of tough and brittle iron fittings to be used in lighting systems. All the fittings were alike in appearance and composition, but some had been heat treated and some had not; the untreated fittings were brittle and would break in service.

The device was built by hooking up 4 pieces of standard laboratory electrical apparatus and winding 2 small hollow coils of fine wire. One piece of apparatus was an oscilloscope, a device which makes electrical waves trace a visible path on a glass screen. When a fitting was inserted into one of the hollow coils, a green line on the oscilloscope screen told whether or not it had been heat-treated.

The test was based on the balancing of magnetic fields in the 2 coils. With a standard casting in one coil, when the tough, treated iron was placed in the other coil of wire carrying an electric current, the magnetic field was increased more than when the brittle, untreated iron was tested. A straight line on the oscillograph indicated equal magnetic fields in both coils.

The method can be used to sort all kinds of small steel or iron parts that have different effects on a magnetic field, such as mixtures of high-alloy and plain carbon steels, mixtures of cementitic and ferritic irons, mixtures of properly and improperly treated high speed steel tools, etc.

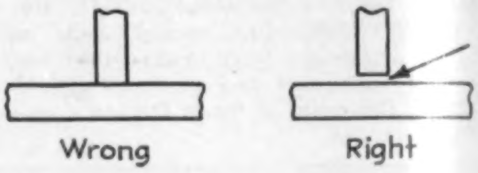
Bench setup for magnetic sorting



Cracked Welds

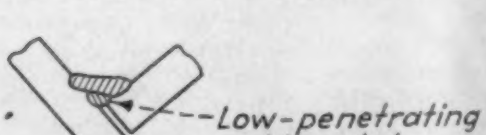
by M. L. Smith
Metal and Thermit Co.

With modern heavy-coated arc-welding electrodes, the weld metal is generally so ductile that if joint design is correct, cracked welds should never occur, particularly in mild steel.



In making heavy fillets, for example, leaving a small space between plates when they are fitted up and tack-welded allows the welds to shrink freely on cooling and thus prevents cracking. Providing exactly the proper spacing, in fact, will permit the plates to be pulled tightly together without causing any locked-up stresses in the weld.

Where high-carbon steels are being welded, the use in the root of the weld of an electrode with limited penetrating qualities reduces pick-up of carbon from the parent metal and prevents excess hardness and strength, and correspondingly low ductility in the weld metal. In some cases, it is desirable to substitute 2-layer welds for single-pass fillets, putting in a small root weld with a low-penetration rod and finishing the weld with a rod having physical properties closer to those of the material being welded.



Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

A Digest of
Important Developments
in the World of Metals

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OF METALS, MILL PRODUCTS, CASTINGS

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Mold and Core Washes

"Mould and Core Washes." Wm. Y. Buchanan. *Foundry Trade J.*, Vol. 65, July 31, 1941, pp.73-75. Practical review.

The author has for a number of years used blacking made from coke only and added to the resultant black-wash such materials as bentonite, Colbond, dextrine, semi-solid core oil, coal dust of high volatile content, and even crude oil. Special additions such as alkalies, intended to improve the suspension of the clays in water, were avoided, owing to their corrosive action on the mixing tank.

The application of crude oil is possible only when an emulsion is used in the mixing process. Coke has a specific gravity of about 1.3, *i.e.* very near to that of water, and is by nature very hard and abrasive toward metal even when finely ground. Coke dust itself tends to settle in water and constant stirring becomes necessary during use.

Compressed-air mixing has been found to be the most suitable method for this purpose. The usual practice is to mix a new batch of blackwash and leave it overnight while the previous batch is still in use, so that there is no break in continuous supply. A typical mixture in use at present is: blacking 224, plumbago 12, bentonite 20 and water 500 lbs.

Specific gravity is the first obvious method of testing blackwash and several forms of hydrometer were tried; the specific gravity bottle was also used. They were found unsatisfactory. Finally, the viscometer method has been generally adopted. The viscometer used by the author consists of a brass cup with a conical bottom, a definite volume of 113 ml. and an orifice 0.146 in. diam.

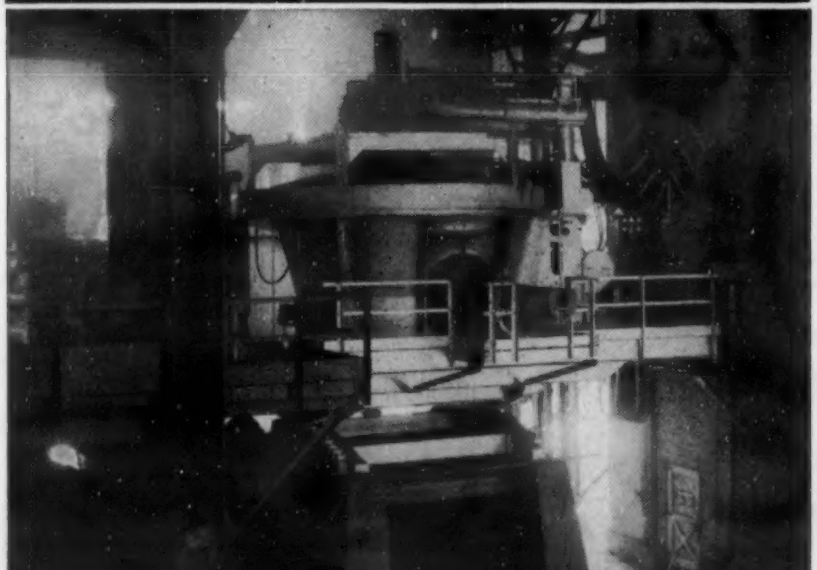
The method of check of blackwash by analysis was also used by the author. By this method a sample can be resolved into its relative percentages of water, blacking and clay. AIK (1)

Core Blowing

"Principles and Practice of Core-Blowing." H. H. Jones. *Foundry Trade J.*, Vol. 65, Aug. 21, 1941, pp. 127-129, 132. Descriptive.

The making of cores by blowing the sand into the corebox under air pressure is an art that has been developed in the last decade. In South Africa, several types of core are being blown in quantity and the

Heroult ELECTRIC FURNACES



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rate of production in some of these cases compares favorably with results obtained overseas.

A number of marked advantages result from producing cores by the blowing method. The most obvious gain is speed. Almost as important as speed, however, is the improvement in quality of the core.

Blown cores will be more uniform in structure, lighter in weight and higher in strength than those produced by other methods. They will be formed more perfectly, have a higher degree of permeability, and due to their smoother skins will impart a better finish to the castings.

A characteristic of a blown core is that the finer sand grains arrange themselves at the outside of the core with the larger grains in the center. Consequently, the skin will be of maximum smoothness and the core will have maximum permeability.

Due to this openness, the cores do not require as many gas vents. However, on large chunky cores it is sometimes desirable to use vent rods.

The main essentials of a core-blowing machine are a sand reservoir with blow plate; some means of filling the sand reservoir and sealing it; and a system of horizontal and vertical clamps to hold the corebox during the blow operations.

The question of the sand to be used depends on the size and shape of the core and the type of metal being poured. The core sand should be thoroughly mixed, preferably in a machine, which will do the job far better and with a reduced percentage of core oil.

The sand should be placed in the mill first, the dry binder, if any, added and after a short time, the core oil. After mixing for several minutes, water may be added to bring the mixture to the desired moisture content, and the mixer run for several minutes longer. Over-mixing should be avoided. AIK (1)

1a. Ferrous

Sulphur Pickup in the Cupola

"Why Sulphur Pickup Varies in Cupola Iron." Roy A. Clark (E. W. Bliss Co.) *Foundry*, Vol. 69, Sept. 1941, pp. 54-55, 139-140. Original investigation.

Various suggestions have been offered for preventing sulphur pickup—to use more limestone; check scrap iron; use fluxes, etc.

After experimenting with all proposals, the author turned his attention to by-product coke. Although his results are incomplete, the study indicates that it is not total sulphur that influences sulphur pickup but the amount of volatile sulphur present.

All raw materials used were checked. The average sulphur content of steel rails was 0.052% S. Limestone, cupola patching stone and other materials, all had less than 0.120% S.

The mixture on which conclusions were based contained 400 lbs. steel rails and 1000 lbs. silvery pig iron. The total weight of charge was 5000 lbs.; using 500 lb. coke between charges, giving a 10:1 iron-to-coke ratio and a weight of bed coke of 4600 lb. The cast iron produced contained an average of about 0.137% S.

With another mixture of 6000 lbs. pig iron, silvery pig, cast iron and steel scrap, with 660 lbs. coke split between charges (a 9:1 iron-to-coke ratio), sulphur pickup was in the same ratio.

The ash of the coke showed very little sulphur. The sulphur was of the volatile type and was not retained by ash. Analysis of another coke showed that the sulphur retained in its ash was so large as to lead to the conclusion that this alone was the answer.

Trial heats made using a coke, with 0.60% S (10.16% retained and 89.84% volatile), showed a drop in the sulphur content of cast iron melted. Therefore, sulphur pickup in cupola cast iron was due mainly to volatile sulphur in coke.

This coke was satisfactory for some time. Soon the cast iron increased in sulphur, probably owing to the manufacturer's changing his cupola coke. This coke was tested and showed lower total sulphur.

This showed that a coke with high retained sulphur was most desirable in avoiding sulphur pickup by the iron. Due to the fact that increase in total sulphur of coke was not compensated by corresponding increase in retained sulphur, the net result was that greater percentage of sulphur in coke, being volatile, was picked up by the cast iron in melting. VSP (1a)

Alloy Iron Castings

"Foundry Technique in the Production of High Strength and Other Types of Alloy Gray Iron Castings." A. E. McRae Smith. *Foundry Trade J.*, Vol. 65, July 10, 1941, pp. 19-21, 30. Review.

B.S.I. specification for cast iron, the use of alloy additions, chill-restraining additions, special role of molybdenum, ultra-strong iron, the acicular structure, limits of phosphorus content, high phosphorus and molding technique etc. are discussed. The alloying elements may be classified into 2

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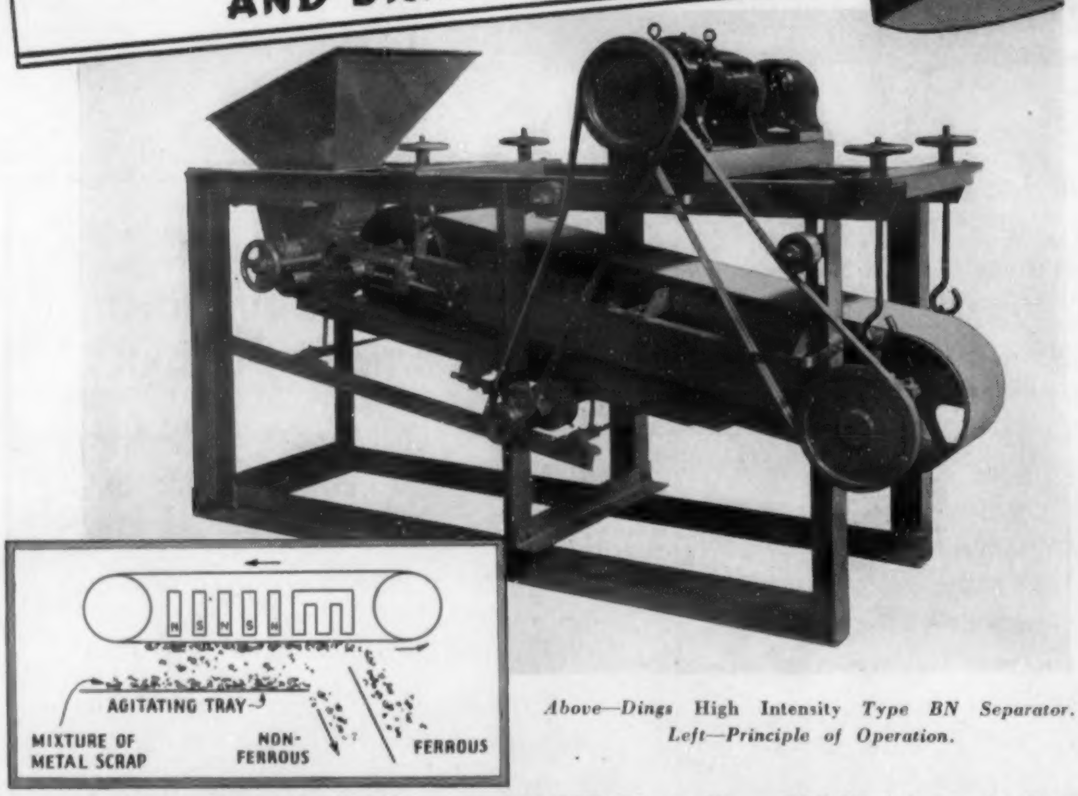

Above—Dings High Intensity Type BN Separator. Left—Principle of Operation.

FROM A RECENT REPORT:

(Concerning Dings Type BN Separator Operating in a Midwestern plant. Owner requested firm name be omitted.)

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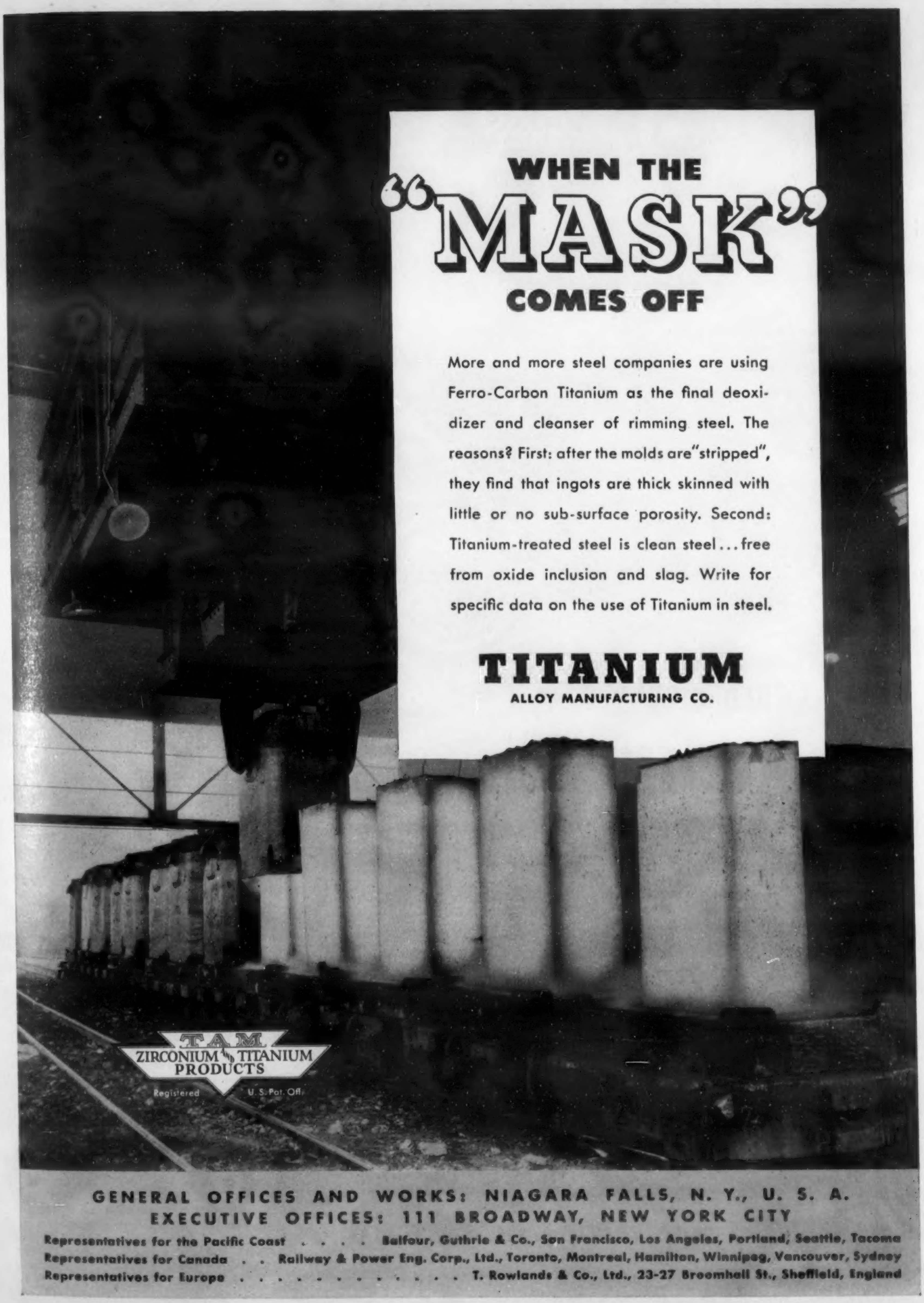

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main groups, namely, chill or carbide forming elements and graphitizing or chill-restraining elements.

The chief chill-inducing elements are chromium, vanadium and boron. These elements increase chill, stabilize the carbides and refine and harden the matrix in pearlitic cast irons.

The chill-restraining elements most commonly used, apart from carbon and silicon, are nickel and copper, the latter only within the limits of its solubility. These two elements also refine and strengthen the pearlitic matrix.

Other graphitizing or chill-restraining elements are aluminum, titanium and zirconium. Aluminum acts like carbon and silicon in that it produces ferrite and softens the matrix, and also coarsens the graphite structure. Titanium when used in small quantities, particularly when oxide is present, strongly refines the graphite structure. Titanium additions may under certain circumstances lead to the formation of "sooty" fractures, with weak dendritic graphite patterns.

Molybdenum is neither a graphitizer nor a strong carbide former, yet it exercises a profound influence on the shape and distribution of the graphite flakes as well as refining and strengthening the matrix to a marked degree. Additions of molybdenum up to about 1.5% effect a very substantial increase in the tensile strengths of cast irons of suitable base composition.

Recently more attention has been paid to nickel-molybdenum cast irons, with alloy contents of 1.5 to 3.0% Ni and 0.7 to 1.0% Mo. Suitable combinations of nickel and molybdenum produce the maximum beneficial effect on the properties of true gray cast iron so far observed.

Such cast irons depend for their properties on the formation of partially or wholly acicular or pseudo-martensitic structures. They can be produced in routine practice with tensile strengths of 55,000-75,000 lbs./in. in the total carbon range 2.8 to 3.0%, and are therefore readily produced from cupola-melted metal. Acicular structures are a function of molybdenum, yet straight molybdenum cast irons have not been very popular.

Increase of phosphorus from, say, 0.3 to 0.7% or even 1%, does not greatly reduce the tensile strength in pearlitic cast irons but does increase or widen the freezing range, at the same time lowering the temperature at which solidification commences. This extension of the freezing range does make such irons more difficult to handle in the foundry, for the production of complicated castings. AIK (1a)

Making Steel Castings

"Principles and Practice Involved in the Production of Steel Castings." D. Clark. *Foundry Trade J.*, Vol. 65, Aug. 7, 1941, pp. 91-93; Aug. 14, 1941, 112-114. Review, discussion.

The electric process, influence of zirconium, the influence of gases, the converter process, molding sand, defects in steel castings, the Randupson process, cause and cure of pinholing, machinery problems, etc. are discussed.

The type of furnace most favored in Australia is the 3-phase 3-electrode Héroult, and for purely foundry requirements this varies in size from 1½ to 7 tons capacity. The largest electric arc furnace in the world today is at the Canton works of the Timken Roller Bearing Co.,—a 100-ton unit with 6 electrodes, virtually 2 furnaces in one shell.

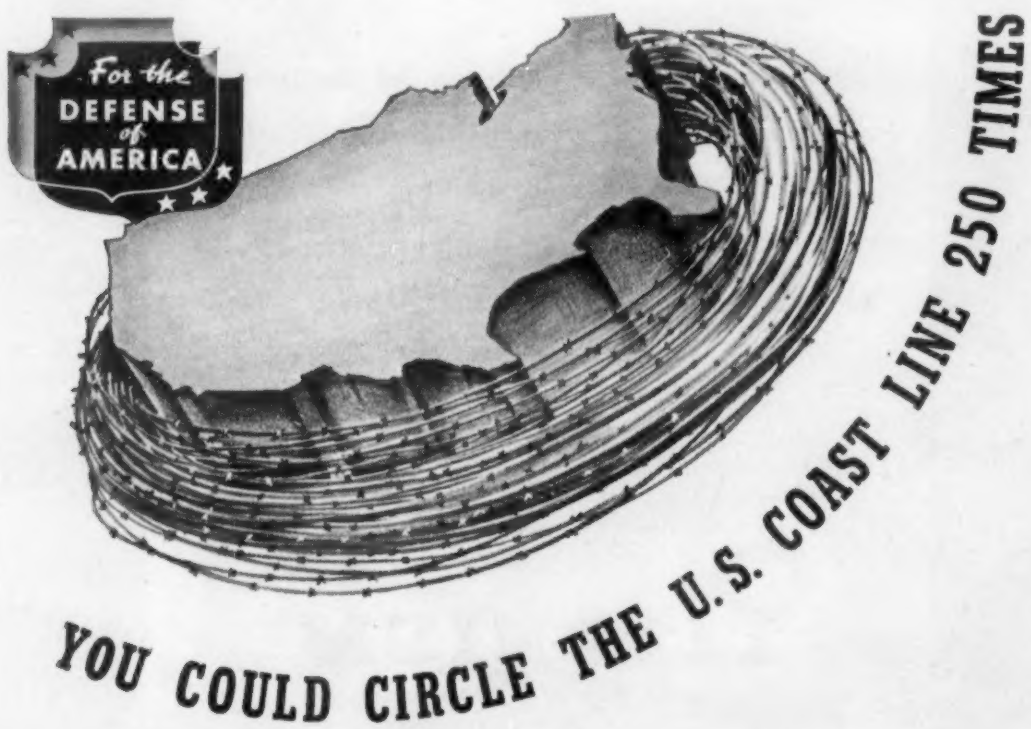
During the war and for a number of years thereafter, the practice was to refine under a carbide slag. The tendency nowadays is toward a white slag with a higher lime content, rather than the typical carbide type which is grayish in color.

The essential differences between the constitution of the two slags is that the white slag carries less crushed coal or anthracite than the other—that is, less than is necessary to form calcium carbide. One advantage accruing from the latter practice is better control of the carbon content in the steel, while another is that the steel tends to exhibit a higher inherent fluidity.

It is well-known that the basic electric steel is much less fluid at a given temperature than that obtained from the converter. A likely explanation is that the latter steel contains dissolved oxides, which evolve heat due to their reaction with manganese and silicon.

Assuming this to be correct, then it follows that saturating electric steel with deoxidizers is bad and likely to produce a steel of such a high viscosity as to render it unsuitable for light castings. Developing this theory still further, it might be postulated that after the deoxidants have been added the melt should be tapped quickly. Zirconium exerts considerable influence and its effect, probably, is to reduce the undissolved gas content.

A new method of de-phosphorizing and deoxidizing steel is a French process by Perrin. In the case of high phosphorus content, the steel is intimately mixed with a basic slag of such analysis that it will chemically combine with phosphorus. To deoxidize, the means employed is exactly the same, except that an acidic slag is used to absorb the oxygen. AIK (1a)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Ingot Mold Life

THE LIFE OF STEEL PLANT CHILL MOLDS ("Zur Frage der Haltbarkeit von Stahlwerkskokillen") O. HENGSTENBERG, K. KNEHANS & N. BERNDT. *Tech. Mitt. Krupp, Forschungsber.*, Vol. 4, May 1941, pp. 127-133. Investigation.

Supplementing the results of previous surveys (see METALS AND ALLOYS, Mar. 1941, p. 331), recent experiments are reported as made on chill molds containing 3.8% C, 1.27 Si, 0.70 Mn, 0.10 P and 0.09 S. The results of the casts made in them were statistically evaluated, and can be summarized as follows.

Burnt-out molds had in general a higher total-carbon content than cracked molds, and the tendency to burn out increases with increasing total carbon. The number of casts made in a mold before failure decreases with increasing total carbon.

The ratio of burnt-out to cracked molds increases with increasing silicon content, and the life decreases with increasing silicon. Increasing the manganese content, however, reduces the percentage of burnt-out molds, and the number of average casts is an optimum at 0.50-0.60% Mn.

A higher content of combined carbon seems to increase life, and increasing graphite content reduces it. Phosphorus and sulphur have little effect, but below 0.1% an increase in phosphorus can have a favorable effect on mold life.

The treatment of the molds has a very decided effect on life. Pouring from bottom increased the life more than 30% over pouring from the top (the usual way). Repairing or grinding the defective spots in a mold also contributes to longer life; an increase of 15% over the normal life has been achieved in some cases.

The time between stripping also is an important factor. The consumption of molds increased from 16 to 25 lbs. per ton of steel if, instead of 8 times, the molds were used 12-14 times a day. Special supervision of the molds in one steel plant increased the life, expressed in number of casts, from 100 in 1933 to 139 in 1939. Ha (1a)

Blast Furnace Material Size

"EFFECT OF SIZES OF MATERIAL ON BLAST FURNACE OPERATION." C. C. FURNAS (Yale Univ.) *Blast Furnace & Steel Plant*, Vol 29, June 1941, pp. 625-630, 668-669. Review and discussion.

Results of various investigations, including some by the author, demonstrate that it is highly desirable to prevent channelling of the gas stream in the stock column. To do this, segregation of large particles in any one part of the furnace should be prevented as much as possible.

Another reason for maintaining uniform distribution of particle size in the stock column is that channelling, with excessive gas velocities, is often an important factor in causing hanging and slipping. Operating with a uniform bed should not cause any great difficulty in getting the gas through the furnace.

Based on these considerations and the desirability of encouraging reactions that produce carbon dioxide and discouraging those that produce carbon monoxide, the author estimates that the optimum size of ore particles is 1/8-1 in.; of limestone, 1-3 in.; and of coke, 2-4 in. All materials should be so charged as to prevent size segregation as much as possible.

More thorough investigation of proportioning of size of materials would lead to better furnace operation and significant financial savings. MS (1a)

1b. Non-Ferrous

Low-Temperature Melting Furnaces

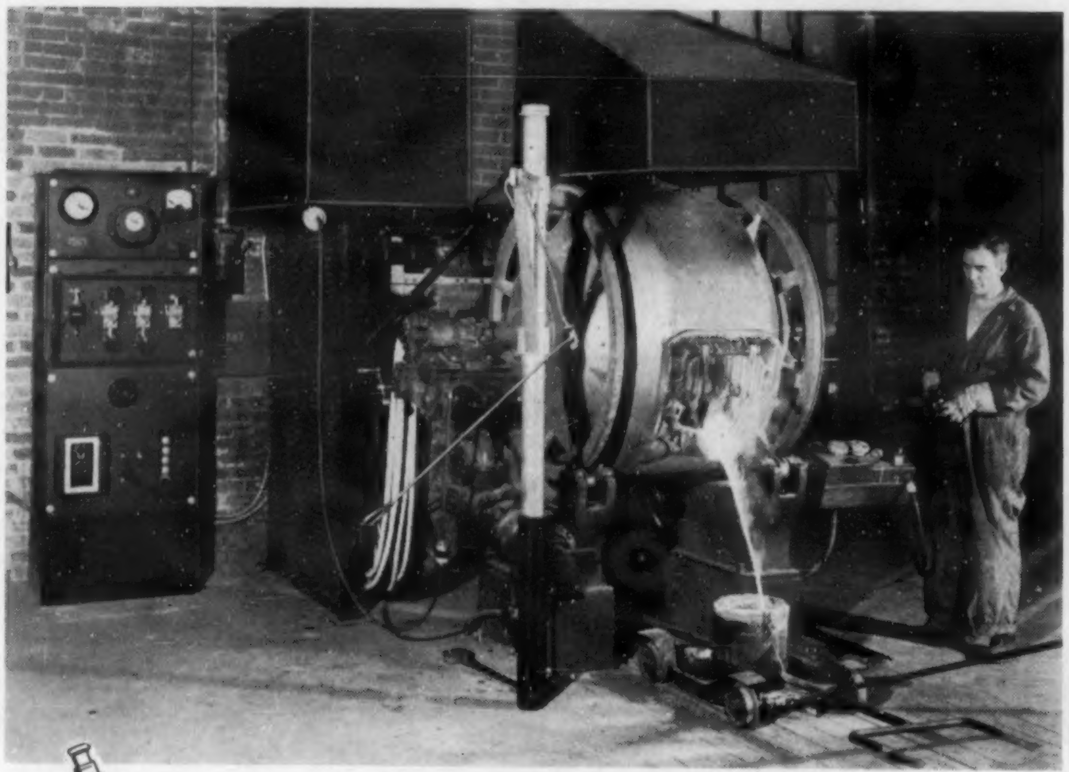
"LOW-TEMPERATURE MELTING." NELLIS SMITH (Central New York Power Corp.) *Steel*, Vol. 109, Aug. 18, 1941, p. 84. Descriptive.

Gas-fired equipment is most widely used for alloys melting at 600°-700° F., such as electrotype metal. In the installation described, the fire-box floor of insulating firebrick is built with steps from the firing end towards the flue outlet. This brings the radiant floor closer to the pot as the flue outlet is approached and as the temperature of the floor decreases with distance from the firing point.

The cross-sectional area of the firing chamber decreases as the hot gases travel from the flame toward the flue and are cooled and contract in total volume. This eliminates cold air leaks into the fire-box. The length of setting is 40 in. The cast iron pot is 32 in. long and its bottom is 8 in. above the lowest part of the setting floor at the firing end.

Three simple atmospheric-type burners inject primary air at the shutter and secondary air directly into the flame at the burner port. All 3 burners are manifolded to a common 1¼-in. supply line. All burners are used during melting with a single center burner for maintaining heat.

An open T in the galvanized-iron flue 3 ft. above the firing level acts as a draft hood and fixes the small draft required at



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a constant level. No blower is required for handling the combustion air and no compressor is needed for supplying gas.

This unit has been in use over 3 yrs. without furnace maintenance or any sign of pot failure. A similar installation using another fuel developed 2 pot failures in one yr. MS (1b)

Bronze Wire for Screen Cloth

"Production of Commercial Bronze Screen Cloth Wire." Benjamin H. McGar. *Wire & Wire Products,* Vol. 16, Oct. 1941, pp. 613-616, 653. Descriptive.

The Federal Specifications for commercial bronze weaving wire require the bronze to contain 90-92% Cu with the balance zinc. The standard gage wire is 0.113 in.

There are 2 established processes for producing the wire—one from hot-rolled billets and the other from cold-rolled rods.

The hot-rolling method begins with either a round or square billet. The billets are heated in any conventional type furnace to about 1500° F., and then hot-rolled 7 passes through the roughing mill, and 9 passes through the intermediate and finishing rolls, reducing the cross section of the rod to ⅝ in. round.

In the cold-rolled method the rods are cast in round cannon molds to 2 in. in diam. and 8½ ft. long. The castings are first drawn on a rod drawing bench to straighten and stiffen them, and then the cast surface is removed in a rotary scalper. The rods are then given 5 passes through the roughing mill, followed by 6 passes through an intermediate mill to 0.750 in. square. On the last pass, the rods are rolled into coils 28 in. in diam.

The coils are annealed in a batch type furnace at 1250° F. for 1½ hrs. After annealing the rods go through a 5-roll straightener and through 10 pairs of grooved rolls, bringing the rods down to 0.325 in. square. The rods are again formed into coils. The 0.325 in. square rods are annealed for 1½ hrs. at 1250° F., then pickled in 10% sulphuric acid solution and thoroughly washed in water. They are then welded to make one continuous coil, drawn down to either 5/16 in. or ¼ in. round, again annealed and pickled.

Both the hot-rolled rods and the cold-drawn and annealed rods are of similar size and have nearly the same physical properties. The surface treatment of the rods is highly important because it determines largely what shade or color the finished wire will have. Three well-known methods are used for cleaning or dipping the rods: (1) 10% sulphuric acid solution, (2) sodium dichromate dip, and (3) nitric-sulphuric acid dip.

No standard procedure has been adopted by industry for reducing the rods to the wire sizes required for the screen cloth manufacturer. One method is described. Ten dies in a large intermediate multiple die machine are used to draw the rods from 5/16 in. to 0.051 in. The first 9 are tungsten carbide, and the last one a diamond. A water emulsion lubricant high in free fats is circulated on the dies during the drawing operation. The finished wire comes from the machine at the rate of 2500 ft./min.

The hard wire has a tensile strength of 112,000 lbs./in.² It is placed on a finishing machine and drawn directly to 0.0113 in., using 13 diamond dies. The same lubricant is used as on the intermediate machine. The finished hard wire has a tensile strength of approximately 130,000 lbs./in.² (1b)

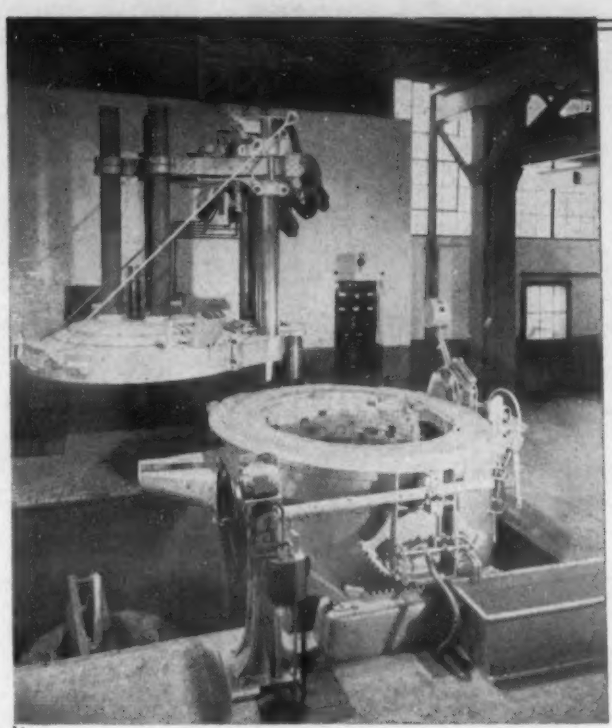

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Illustration shows top charge type LECTROMELT furnace with roof raised and rotated to one side to permit quick charging with drop bottom bucket.

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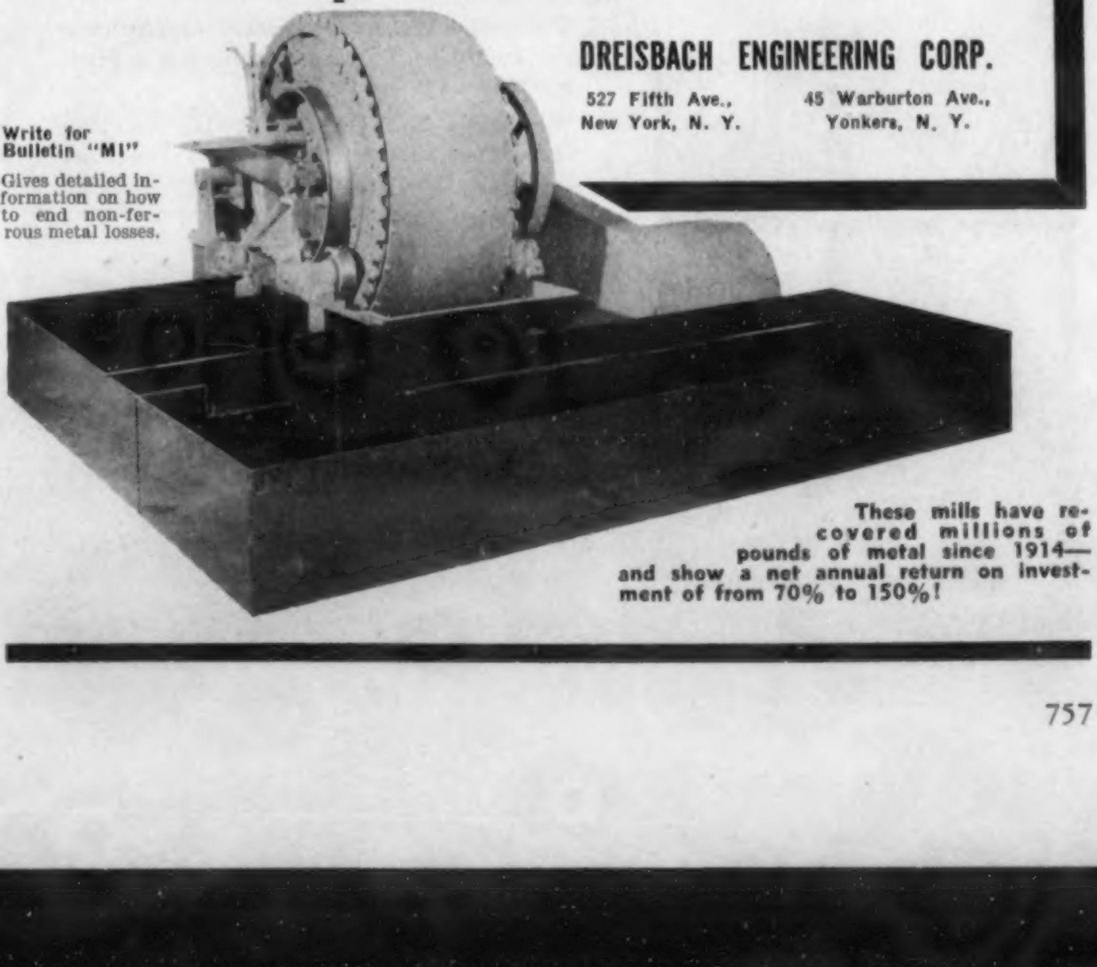

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2

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Chromium Plating Glass Molds

"Chrome Plating Saves Glassware Molds." D. McGregor. *Am. Machinist*, Vol. 85, Sept. 3, 1941, pp. 854-855. Practical.

Since molten Pyrex glass may have a temperature of about 2800° F. when it hits the mold, plungers and molds made of chilled gray iron lose their high polish quickly. After 4 hrs., a heavy oxide coating is formed on them; after 30 hrs. hair-like cracks on the molds are distinct enough to show up on the glass.

The first improvement was the use of a close-grained chilled Meehanite E iron for the mold. After the mold has been machined and polished, a lead anode is prepared by pouring into the back of the mold on the plunger. The lead anode is then covered with 5/16 in. holes to allow the chromic acid to circulate freely in plating.

After the mold has been cleaned thoroughly, it is set up in the plating outfit about ½ in. from the anode. The chromium plating is done in a chromic acid bath with 3 lbs. chromic acid + 0.4 oz. sulphuric acid per gallon of water; temperature is maintained at 80° F., voltage at 6 v., current at 250-300 amps. for 20 min.

The plunger is plated in the same way except that standard strip lead anodes are usually sufficient. If old molds or plungers are being replated, the old plating must be stripped in caustic soda before the articles are replated.

The chromium plate can be buffed to a high finish. If a portion of the mold is required to withstand severe friction, hard chromium plating is used.

The chromium plating has trebled the life of molds for Pyrex. Soda glass is pressed at a considerably lower temperature (1800°-2000° F.), so service conditions are not so severe. However, the use of chromium plating gives a more brilliant article and allows thin-walled pieces to be pressed that previously had to be blown. [*Highly alloyed tool steels and stainless steels are frequently used in the U.S.A. instead of cast iron.—J.Z.B.*] JZB (2)

A New Composite Coating

"Corronizing." R. Rimbach (Standard Steel Spring Co.). *Mo. Rev., Am. Electroplaters' Soc.*, Vol. 28, July 1941, pp. 533-541. Descriptive.

"Corronizing" is a composite coating consisting of a layer of nickel, plated on the base metal, which is followed by a layer of zinc or tin. The coating is heated at a temperature of 500° to 750° F. for periods up to 6 hrs.

The sequence of operations in corronizing is similar to ordinary plating procedure and consists of cathodic cleaning, pickling if necessary, anodic pickling in sulphuric acid, nickel plating, zinc plating from the acid bath, and finally the heat treatment.

The coating is ductile and adheres well to the base metal. It is used for fly screen wire, fence wire, motor parts, and in general wherever corrosion resistance is desired. For coatings of equal thickness, corronizing is said to last several times longer than galvanized coatings. Bright corronizing can also be produced. AB (2)

Soft Metal Tools for Forming

"Making and Using Soft Metal Tools for Pressing Short Run Panels." Alastair McLeod. *Sheet Metal Inds.*, Vol. 15, July 1941, pp. 906-910; 917-920. Practical. Continuation of a series (for previous installment, see Metals and Alloys, Aug. 1941, p. 214).

The analysis of soft metal used in dies varies widely. Antimony in lead tools may be anywhere from 4-12%.

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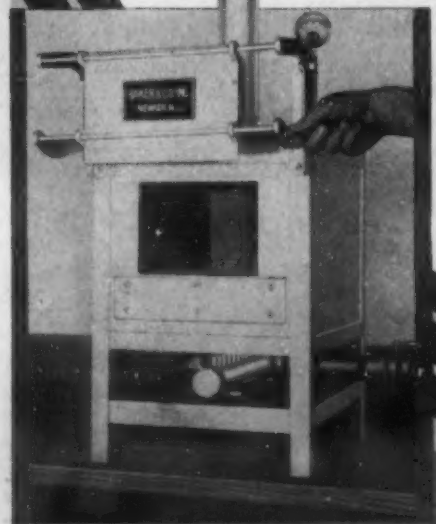

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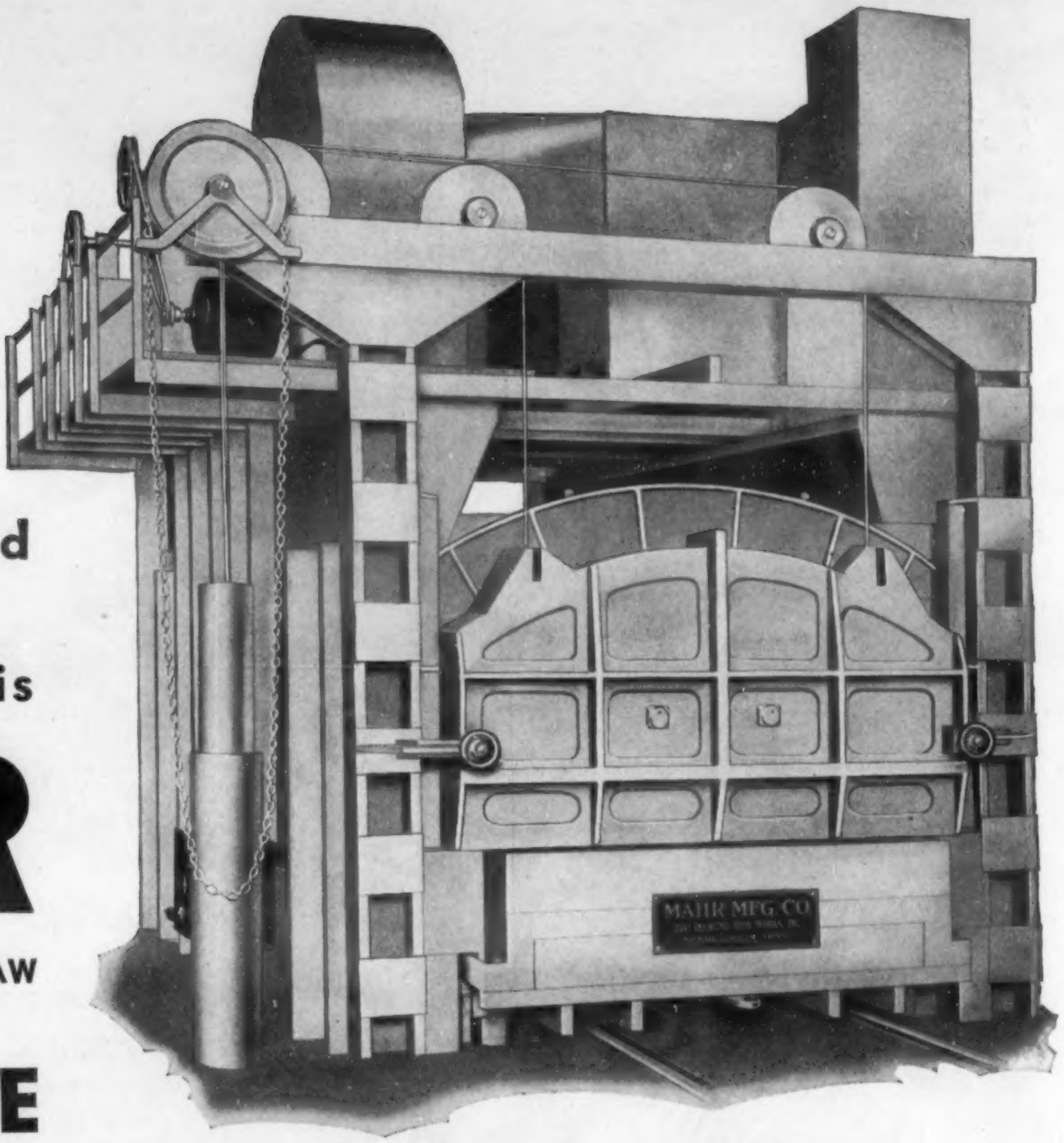

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Distribution ducts in heating chamber are constructed of special refractory design, thus eliminating the necessity of costly alloy and reducing maintenance costs . . . All of the features of MAHR standard car type construction are incorporated in this furnace, assuring the use of a unit with rugged construction, efficient operation and long service-life.

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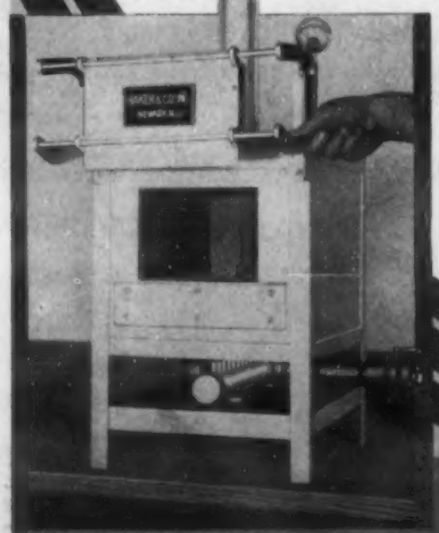

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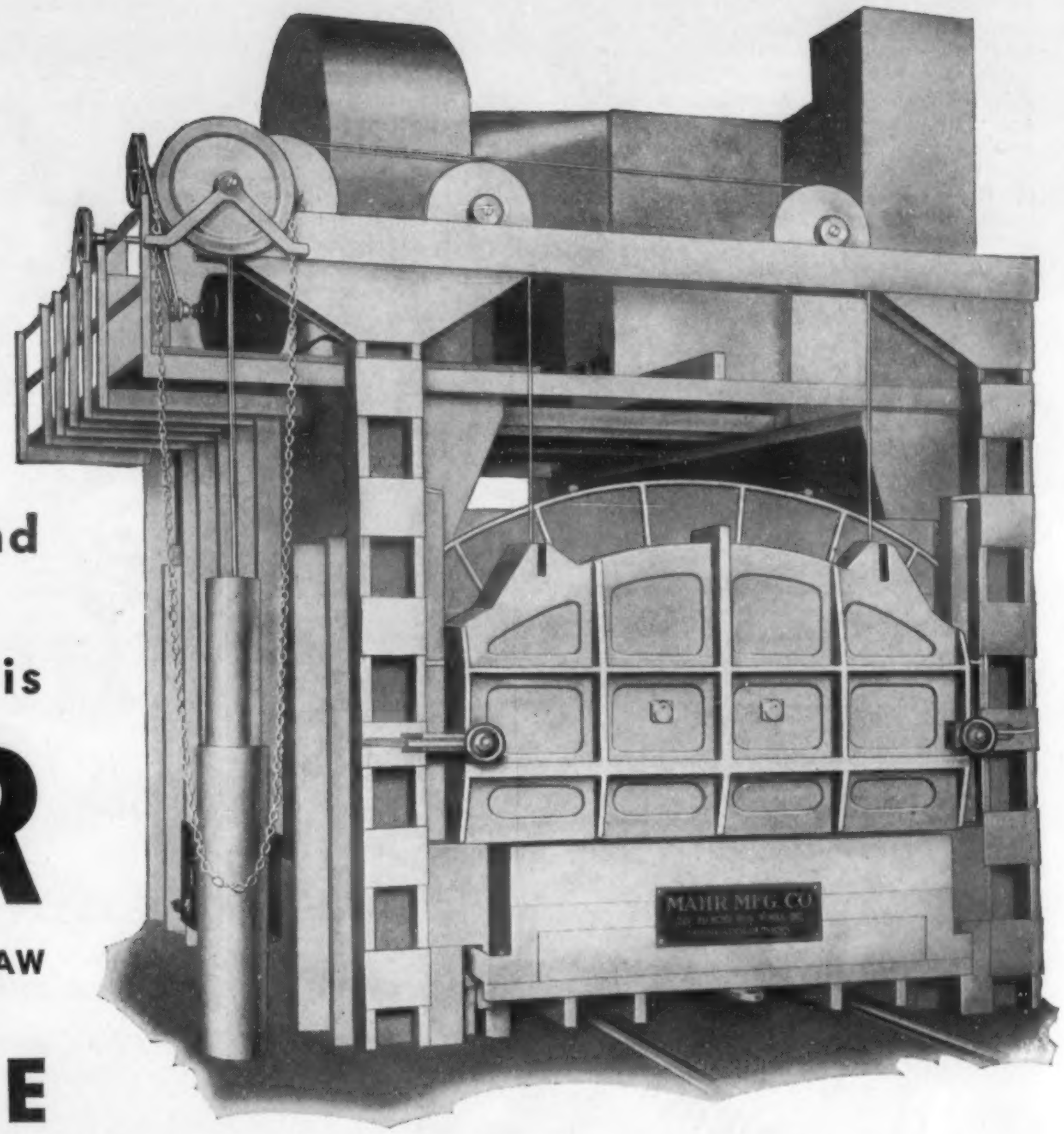

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of aluminum, lead, cadmium, tin and antimony in the alloy should also be avoided as all of these shorten the life of the die.

The zinc alloys known as Zamak 2 [4% Al, 3 Cu, 0.03 Mg, bal. Zn] or Kirksite are widely used in the United States for production of dies for drop hammer work. However, in England Durak alloy [no analysis given] has been adopted as it is harder, stronger, more stable, and less susceptible to embrittlement than Zamak 2.

In casting relatively small dies, the female die is used to form the punch; however, if the tools are larger than 1 ft. in diam., the solidification shrinkage is so great that there is an undesirable gap exceeding the thickness of the metal to be drawn. Therefore, in the case of large tools, a plaster cast of the punch is produced and the Kirksite is cast into a sand mold.

Over this is poured the die of the same alloy; consequently the shrinkage tends to bind the die close to the punch rather than allowing the punch to shrink away from the die. A coating of a special liquid compound consisting of a water suspension of iron oxide, graphite, and sodium silicate with a binder and a mold inhibitor is sprayed over and over on the hot punch to build up a thickness approximating the metal to be stamped. This coating provides the necessary clearance and facilitates separation of the punch and die after the casting has been made.

For best results the punch is heated to about 500° F. Casting temperature should be 775-825°F.; lower temperatures cause brittleness and a separation of a heavy sludge of copper-zinc alloy; higher temperatures cause excessive shrinkage, warpage, and draw marks. Pouring should be done very slowly until the bottom of the mold is covered.

Various methods are used for blanking and stamping with these dies, some of which are modifications of the Guerin process in which rubber is used as a punch [described in METALS AND ALLOYS, Oct. 1940, pp. 436-441]. Design of the part and method of applying pressure are key factors.

Because the zinc tools are harder than the lead the latter is used only as a male tool since the punch shape tends to conform to that of the die with each successive blow. Since the lead tool exerts pressure at every point of the zinc tool, close tolerances can be maintained.

The number of pressings obtainable from one set of these tools varies from 200 to 10,000. In pressing operations, the draw plate may be of the same material as the blank; a number of plywood rings, 1/4 in. thick, are placed on the metal draw ring, one plywood ring being removed after each blow.

Another method involves the use of slabs of rubber to interpose at highly stressed points. In such pressing operations, the shape of the blank is sometimes very important; often the edges are nibbled or stack cut.

In addition to the soft metals and rubber, there is growing use of press tools (for use with rubber) made of magnesium (Germany), plastics or reinforced wood.

JZB (2)

2a. Ferrous

Weld Cracks

A Composite

One important factor in steel weld-quality is freedom from cracks that occur even in the absence of external stresses. Such cracks have been blamed by different workers on a variety of causes, and in the first article reviewed below, all possible factors are explored. The second article points the finger specifically at one alleged culprit—parent metal quality.

A correlated abstract on welding cracks is presented by W. SPRARAGEN & G. E. CLAUSSEN ("Weldability—Weld Metal Cracks. A Review of the Literature to July 1, 1939." *Welding J., N. Y.*, Vol. 20, July 1941, pp. 289s-305s). Cracks in weld metal are considered to be of the same type as the "hot tears" in castings caused by hindered contraction. The weld metal cracks are designated "auto cracks" in order to provide a distinctive name.

The auto cracks are nearly always parallel to the direction of the weld, and are found in the first bead to be deposited in a fillet or butt weld. When they reach to the surface of the weld, the auto cracks are oxidized or blued, which indicates that they form at an elevated temperature.

In concave fillet beads the cracks start at the surface, while in convex beads the cracks start at the root, do not always reach the surface, and may thus escape detection. Occasionally auto cracks may form transverse to the direction of the bead.

An increase in carbon in cast steels decreases the stresses that cause hot tearing, but increase in carbon in highly-killed weld metal slightly increased auto cracking in the Tee joint test. Silicon appears to be harmful in inducing cracks when insufficient manganese is present. Manganese in the range of 0.01-1.0% has no influence on auto cracking.

SCALE REMOVED
FROM CARTRIDGE BRASS
in 3 to 4 minutes . . . with FERRISUL!

HERE'S a simple, easy way to speed production and improve quality in processing copper and copper alloys—*use Ferrisul (anhydrous ferric sulfate) in your pickling solutions!*

With cartridge case brass, Ferrisul is removing scale in 3 to 4 minutes . . . producing an exceptional appearance on partially completed cartridge cases . . . and leaving an excellent surface for subsequent drawing operations.

On all types of copper and copper alloys, you get a complete pickle with Ferrisul and an END TO RED STAIN . . . for Ferrisul reacts with red scale, oxidizing it to black cupric oxide which dissolves immediately in the same bath.

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Phosphor Bronze
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Nickel Silver
Stainless Steels

FERRISUL
For better metal pickling

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SERVING INDUSTRY . . . WHICH SERVES MANKIND

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250% more abrasion and wear resistance than any black finish on the market—*guaranteed.*

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50 hours and more, salt spray test with JETAL and Jetoil—*guaranteed.*

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The effect of sulphur on auto cracking appears to depend upon the form in which it is present. Phosphorus, hydrogen and oxygen are probably not effective in auto cracking. The presence of slag inclusions in weld metal appears to favor auto cracking.

Auto cracking is attributed to low ductility and low strength of weld metal at high temperature in the range of negligible elongation below the solidus. The greater the rigidity of the plates being joined, and the greater the gap between them, the more favorable are the conditions for auto cracking.

On occasion auto cracks have been associated with the type of electrode, whether lightly or heavily coated or cored; the type of coating, whether acid or basic; and other factors. These results, however, are not always confirmed by other investigators. Preventive measures are the use of suitable electrodes, pre-heat, peening, and proper welding sequence.

The most popular test for determining the auto cracking susceptibility of a particular base metal and electrode combination is the Tee joint test. One bead is deposited on one side of the Tee and the second bead is deposited immediately after the first and examined for crack formation. With highly sensitive electrodes the first bead cracks before the second bead is deposited.

J. Muller ("The Cause of Welding Cracks in Aircraft Steels." *Welding J., N. Y.,* Vol. 20, July 1941, pp. 309s-316s; a translation by S. Reiss from *Luftfahrforschung,* Vol. 17, No. 4, Apr. 1940, pp. 97-105) discusses the behavior of thin-walled parts up to 3 mm. in thickness during gas welding. From 1928 to 1933 a 0.30% C chromium-molybdenum steel had been successfully welded in Germany into aircraft structures, but in 1933 when aircraft production increased the incidence of a new type of failure, welding cracks or fissures, assumed alarming proportions.

Tests were made and indicated that welding technique was not at fault and that weld stresses were a necessary condition for the occurrence of weld cracks, but were not sufficient alone to account for the cracking. Steel of good quality, which was not subject to cracking, could be made highly susceptible to cracking by annealing the steel at 1850° F. in a furnace with a gas that loaded the iron with sulphur by diffusion.

Higher contents of sulphur, carbon and phosphorus are regarded as principally effective in causing cracking, but a far greater effect was shown in the melting and teeming practice of the steel used. With a longer boiling period at higher furnace temperatures and casting at higher temperatures the steel rolled from the ingot was less susceptible to weld cracking. The carbon content of the latter was 0.23-0.27% as against a former range of 0.29-0.36%.

The German aircraft industry now specifies limits of sulphur, carbon and phosphorus and requires electric furnace production of the steel to remove the defect of weld cracking. WB (2a)

Oxyacetylene Flame Hardening

"Oxyacetylene Flame Hardening." J. G. Magrath (Air Reduction) *Am. Machinist,* Vol. 85, June 25, 1941, pp. 581-583; July 23, 1941, pp. 698-699; Aug. 6, 1941, pp. 748-749; Aug. 20, 1941, pp. 804-806; Sept. 3, 1941, pp. 849-851; Sept. 17, 1941, pp. 915-917. Practical review.

Selective hardening with a torch has been done for 30 yrs. by toolmakers hardening the edges of sheet metal contour gages. Gear teeth were flame-hardened in England over 23 yrs. ago. However, the first large scale application was the introduction in 1937 of flame hardening for rail ends.

The main advantage of flame hardening is the ability to limit the hardness to shallow surface areas without affecting desirable properties in the base metal. Moreover, flame hardening is much quicker than conventional furnace hardening and can be used for many parts that are too large for available furnaces or that might warp unduly. Cracking, distortion, and straining are decreased to a minimum. Finally, flame hardening permits selective hardening whereby only the parts that must be hard are hardened while the rest of the article retains maximum toughness.

Wrought Steels

If the proper steel is not used, insufficient hardness on one hand, or cracking from excessive hardening on the other, may occur. "Fine grained" steels are preferable to avoid grain coarsening if over-heated. If surface hardness is a primary factor, no advantage results from the use of alloy steels.

Typical hardnesses obtained in carbon steels after flame hardening with a water quench are:

S.A.E. Type	Brinell Hardness
X1335	500
1040	580
1050	615
1095	700

Flame hardening can be applied to all

It reduces a whole series of processes to ONE OPERATION

☆ ☆ ☆

ROCKWELL
ROTARY
ANNEALING
FURNACE
(retort type)

THE demand for brass cups by cartridge manufacturers will soon eclipse all other production in the brass industry. Brass mills will be limited only by their capacity to produce them.

Rockwell Rotary Annealing Furnaces of the Retort Type, like the one shown above, running since the beginning of the present war, have an outstanding record for annealing 30 and 50 calibre cartridge case parts.

The unit consists of a skip taking the work from the floor and charging it into a washing machine unit. From this point it travels through a washer, annealing furnace, and various stages in the pickling and washing machine.

The cartridge case parts are handled through all the operations in a continuous even stream. They are charged hard and oily and discharged soft, pickled and dried. This furnace is exceptionally economical from the standpoint of labor —there is no intermediate handling—as well as in fuel and the use of acid.

You can do your share if you have the right furnace equipment—NOW is not too soon.

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HEAT TREATING

Old man "Reject" is a master saboteur. And when he steps in at the heat treating stage—he wrecks hours of forging, casting and machining time.

The even, well distributed and controlled heats in modern furnaces practically eliminate "Rejects". Even the art of loading has been improved to obtain bigger batches, with conveyor loading and complete atmospheric control. The amount of floor space required is frequently reduced.

The Spencer Turbo-Compressor, a reliable source of clean air at correct pressures without surges, has contributed greatly to the art of heat treating small parts.

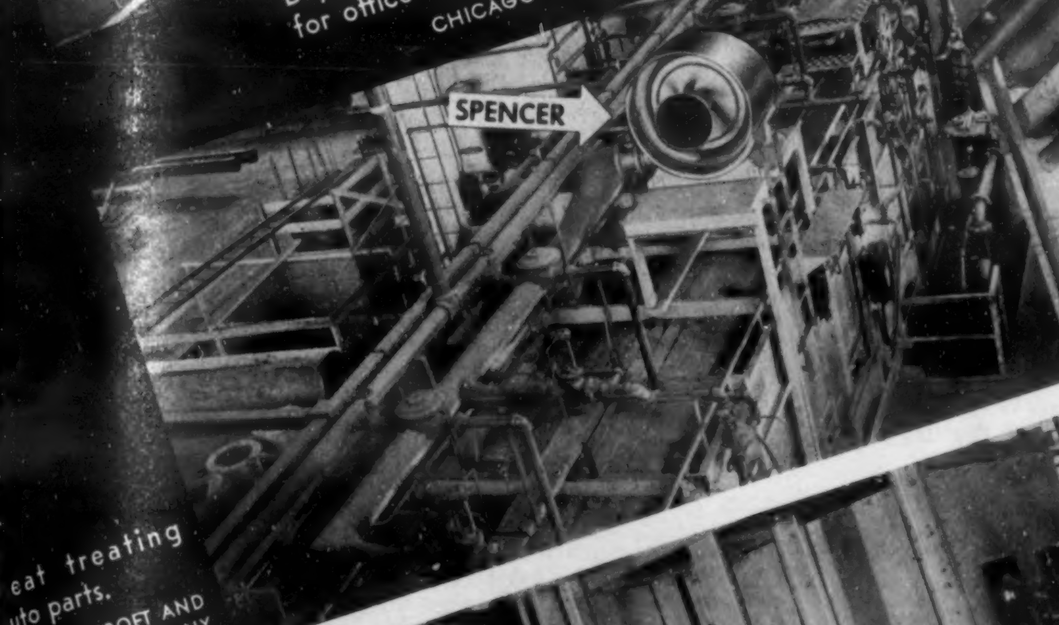
This series of advertisements pictures applications of Spencer Turbos made by 20 leading furnace and oven manufacturers. Ask them about your heat treating problems and the Spencer Turbo.

THE SPENCER TURBO-COMPRESSOR DATA BOOK ON REQUEST

Machine Parts

Rotary hearth normalizing furnace. Heating starter rings.
INDUSTRIAL HEATING EQUIPMENT CO.

Dry gas, bright annealing furnace for office equipment parts.
CHICAGO FLEXIBLE SHAFT CO.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Three rotary drum type furnaces for heat treating and drawing lock washers.
CLAUD S. GORDON CO.
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Stress relieving and annealing. Cast steel elevator parts.
THE PHILADELPHIA DRYING MACHINERY CO.

S-209-H

FOR
- Agitation
- Combustion
- Exhaustion
- Gas Boosters
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- Airplane Testing

SPENCER
HARTFORD
Turbo Compressors

35 to 20,000 cu. ft.
1/3 to 300 H.P.
8 oz. to 5 lbs.

THE SPENCER TURBINE COMPANY • HARTFORD, CONNECTICUT

S.A.E. carbon steels with over 0.35% C. Alloy steels suitable for flame hardening include: S.A.E. T1335-1340; 2330-2350; 3130-3140; 4135-4150; 5140-5150; 6135-6150. Examples are given of applications such as plug valves where flame hardening has eliminated galling and scoring.

Flame hardenable alloy steels are recommended when higher core strength and shock resistance are needed than are available with carbon steels. Steels such as S.A.E. 3100, 4100, and 6100 series are resistant enough to softening upon tempering so there is almost no intermediate zone of low hardness below the flame-hardened case.

Brinell hardness figures are given for a number of alloy steels after flame hardening and quenching in compressed air or water; for steels with 0.3-0.5% C, the hardness is generally around 500-600 Brinell. Stainless steel (S.A.E. 51210) was hardened to 444 Brinell with either an air or water quench.

Steel and Iron Castings

Steel castings can be flame hardened but the surface layer may be 30-40 Brinell lower than would be expected unless the decarburized zone is removed by machining. Plain cast iron can be flame hardened to 486-555 Brinell.

A number of alloy cast irons respond satisfactorily, but they should contain as much of the critical-point-lowering elements as possible. Attainable Brinell hardnesses after flame hardening with a water quench vary from 436 to 578 for a group of nickel, nickel-chromium, chromium-molybdenum, and nickel-chromium-molybdenum alloys. It is claimed that chromium, nickel molybdenum or manganese improve core characteristics and benefit hardness and depth of case.

Meehanite irons have attained 450-560 Brinell on flame hardening, and pearlitic malleable irons 401-525. Greater care is exercised in these applications as compared to high carbon steels to avoid burning or fusing (especially with Meehanite). Best results are obtained on machined surfaces as the decarburized surface areas of rough castings will not respond readily. Black heart malleable iron can also be successfully flame hardened.

Heat Input

Although flame temperature is around 6000° F., the rate of heat input must be controlled so that the surface of the steel is not overheated. Also a constant distance must be maintained between the tip of the inner flame cone and the surface of the object to prevent overheated spots.

The depth of hardness penetration can be controlled by the speed of operation:

Flame Hardening (Progressive Method) Speed of Tip Travel, in./min.	Approximate Depth of Hardening (in.)
2	5/16
3	1/4
4	3/16
5	1/8
6	1/16
7	1/32

If the desired depth of hardness is 5/16 in. or over, there is danger of overheating or decarburization with the progressive method. With the spinning method of hardening, however, almost any depth can be obtained satisfactorily. JZB (2a)

Grinding Rolls for Mirror-Finish

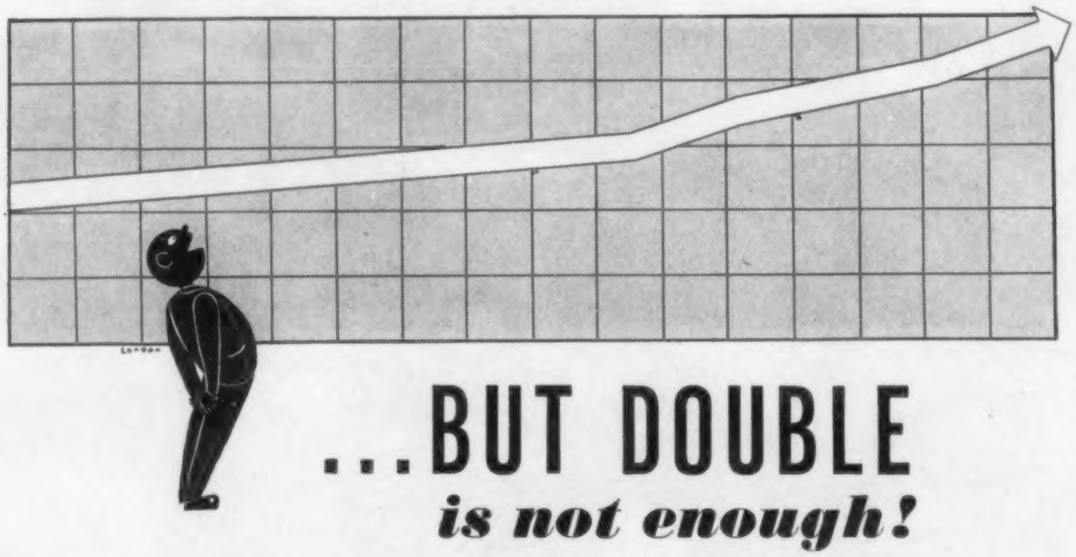
"Ultra-Finish—What Is It? How Is It Obtained?" H. J. Wills (Carborundum Co.) *Steel*, Vol. 108, June 30, 1941, pp. 52-54, 86; Vol. 109, July 21, 1941, pp. 56-58, 60; July 28, 1941, pp. 78, 80, 88; Aug. 11, 1941, pp. 92, 95-96. Descriptive.

With ultra-finish rolls, the product can be given a "mirror" finish directly by the rolls. These rolls are used on steel, copper and brass in strip and sheet form. Such a product makes polishing and buffing after fabrication unnecessary.

To obtain such highly finished material, the rolls must be still more highly finished. Standards for "ultra-finish" on rolls for which some are striving are: (a) There should be no surface flaws such as scratches, ridges, holes, cracks or checks; (b) any waves should be not less than 1 in. long and not more than a few micro in. high; (c) for continuous cold-mill rolls, surface roughness may be 4-7 micro in. r.m.s. (root mean squares); (d) roughness of temper rolls should be 1-3 micro in. r.m.s.; and (e) high finish strip and Steckel-mill rolls should have roughness of 0.5-1.0 micro-in. r.m.s.

The most important means for securing such smoothness is to prevent the appearance of flaws, which are caused by poor condition of machine, dirty coolant, poorly selected wheels, or unskillful manipulation of wheel. Condition of the spindle of roll-grinding machine determines quality of work with regard to chatter, work concentricity, burning and scoring; the grit, grade and type of bond of wheel that may be used are also influential.

High-quality spindles with properly



Doubling production is getting to be an old story these days. As the pace of industry quickens, responding loyally to the urgency of the national crisis, all previous estimates of the country's producing capacity will probably go by the board.

Electrode production, for instance, is now approximately twice that of 1940. By 1942 it will be increased substantially again.

Electrode manufacturers are taking steps so that no user will be embarrassed by electrode shortage. But during this "make ready" stage buyers will be more certain of always having electrodes on hand if they order electrodes when they order steel.

In the meantime, Murex engineers are at your service — to help speed fabrication of welded products and cut costs.

MUREX HEAVY COATED ELECTRODES
METAL & THERMIT CORPORATION • 120 BROADWAY, NEW YORK
ALBANY • CHICAGO • PITTSBURGH • SO. SAN FRANCISCO • TORONTO
THERMIT WELDING — STANDARD FOR 40 YEARS FOR WELDING RAILS AND HEAVY EQUIPMENT

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FURNACES FOR
Armament

This bulletin will help you select heat treating equipment for your armament work

Furnaces for Armament, available now, discusses the application of heat treating furnaces to practically every one of the major types of contract work being allotted today. All of the information presented is based on practical data obtained in installing furnaces for armament work.

A section of the bulletin is devoted to each of the following: Aircraft Parts, Cartridge Cases, Gun Mounts, Cartridge Clips and Links, Machine Gun Parts, Tools and Dies, Bullet Cores and Tank Parts.

Actual installation photographs are given in all cases. Furnaces for Armament shows *what* equipment is being used, and *how* it is being used to meet the close specifications called for today. It is available for the asking. Your copy will be mailed promptly

LINDBERG ENGINEERING COMPANY
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Heat Treating in the Movies . . .

The editors of "Heat Treating Hints" present a full-length sound-on-film Kodachrome movie entitled "Heat Treating Hints." Here is a film prepared by practical heat treaters for their fellow craftsmen and the younger men in heat treating. Practical, instructive, it illustrates valuable tips on the best modern heat treating practice. Make your arrangements now to show "Heat Treating Hints" at your plant or chapter meeting.

LINDBERG
FURNACES

lapped cap or sleeve-bearings of bronze or Babbitt, with right oil and heat clearance, will permit the use of soft wheel gradings. Direct driven spindles, or connected to motor through a coupling, must be alined carefully.

If the motor is integral with spindle, the assembled unit must be balanced with extreme care. All vibration, as well as worn guide-ways, loose headstocks and tailstocks, poor machine foundations, weak neck-rests and lack of lubrication on necks must be avoided.

High-grade Babbitt bearings are preferable. Bronze bearings should be tightened to minimum clearance when taking finish cuts. Bearings should always be heated up by a preliminary running of the machine before grinding.

If more than one grinder is available, one should be used for roughing cuts only and another for finishing only. Speed variations, heating of neck-rests, and faulty roll necks should be avoided. Roll supports or neck-rests should be slightly shorter than the journal bearings unless the necks are newly ground. The width of the rests should be kept at a minimum.

Good lubrication, preferably with white lead, is essential. The rests should be thoroughly lubricated during grinding. After truing in the machine, the wheel must be rebalanced.

The surface of an ultra-finish roll must be built up gradually, using a series of grinding-wheels of decreasing grain penetration and size. The finest practicable grain size down to 600 should be used for ultra finishes. Every wheel should be carefully "sparked out," even when it is to be followed by finer grit wheels. Coolants must be clean and free from grit.

In the cutting cycle, plain filtered water, with a slight amount of solute oil if desired, is used. In finish cycle, with the same wheel, a grease bag is applied to roll and the water supply reduced.

For chilled-iron rolls, silicon carbide wheels are used to give a high luster, and aluminum oxide for a satin finish. The latter wheels are used for grinding hardened or high speed steel rolls for Steckel mills. To obtain a luster, special silicon carbide or aluminum oxide wheels are used for final grinding. Resinoid bonded diamond wheels are best for tungsten carbide Steckel-mill rolls.

For ultra finishes, work speed should be as rapid as possible, short of causing vibration, and ratio of traverse to work speeds should be low. For roughing cuts, best practice is to traverse ½-⅔ width of wheel per revolution of work; for finishing cuts, no more than ¼ in. per revolution; for final finishing, not more than 2 in. per min.

A sharp diamond tool is best for dressing wheels for ultra finish. Slow hand traverse and shallow diamond feed should be used. Wheels finer than 220 grit should never be contacted on their faces to "set" the diamond, and should never be rough dressed. MS (2a)

Finishing Electric-Flatiron Parts

"Cleaning and Bright Plating Iron and Steel Parts of Electric Irons." F. A. Maurer (Gen. Electric Co.) *Mo. Rev. Am. Electroplaters' Soc.*, Vol. 28, Sept. 1941, pp. 695-707. Descriptive.

Four general types of parts are plated: polished cast iron bases, partially polished tops drawn from cold rolled steel, steel stampings, and small parts such as screws and nuts, which are barrel-plated. When possible, the lubricants and oils used in the machining operations are chosen with a view of ready removal.

Parts, other than those barrel plated, are cleaned and plated in fully automatic conveyors, which carry parts through 15 tanks. Losses chargeable to faulty nickel plating are about 1.5% of the production.

Anodic cleaning rather than cathodic cleaning, is used. Spray rinses are automatically operated.

Bright nickel plating is used. Stray currents through the lead heating coil are detrimental as they oxidize and decompose the brightener. In the bright nickel plating process used, the brightener is a derivative of the dye, fuchsin.

To make the plate more ductile, a modifier, consisting of a sulphonated benzene or naphthalene derivative is added. The bright nickel deposits are color buffed on automatic equipment, electro-cleaned and chromium plated.

The ratio of Cr_3 to H_2SO_4 in the chromium bath is 67 instead of the usual 100. This is said to operate more effectively on passive nickel. The chromium is color buffed to prevent finger staining.
AB (2a)

Electro-Cleaning of Steel

"The Contamination and Electrolytic Cleaning of Cold Rolled Steel." Ernest H. Lyons, Jr. (Meaker Co.) *Trans. Electrochem. Soc.*, Vol. 80, 1941; Preprint No. 12. Descriptive.

The large increase in the production of cold-rolled steel and its extensive use as a base metal for electroplating has directed

Cut Your
CLEANING and
DESCALING Times
BEFORE
AFTER

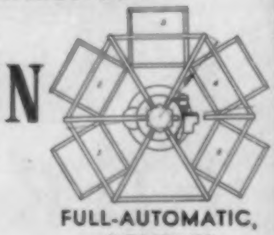
The Bullard-Dunn Process speeds up cleaning and descaling operations because it works rapidly and because it can be conveyorized. Scale-free and heavily scaled parts can be treated at the same time without damage to the former. Where work is to be electroplated, the scale or oxide removal and the plating can be done on the same conveyor. This eliminates unnecessary handling and times the operations to the minimum required, thus assuring a uniform and rapid flow of production. Bullard-Dunn has been used for years by many well known companies. One of the two largest manufacturers of airplane engines, for example, has eleven operating units.

Notice the features listed at the right. If your present cleaning and descaling method lacks even one of these features, write today for booklet giving complete information about the Bullard-Dunn Process.

THE BULLARD-DUNN PROCESS DIVISION
OF THE BULLARD COMPANY
BRIDGEPORT CONNECTICUT

CHECK THESE FEATURES
- Rapid and economical
- Easy to operate
- No dimensional changes
- No etching
- Descales recesses
- Produces chemically clean surfaces
- Can be fully conveyorized
- Long solution life
- Rust protection of parts after descaling

BULLARD-DUNN
Process


FULL-AUTOMATIC,
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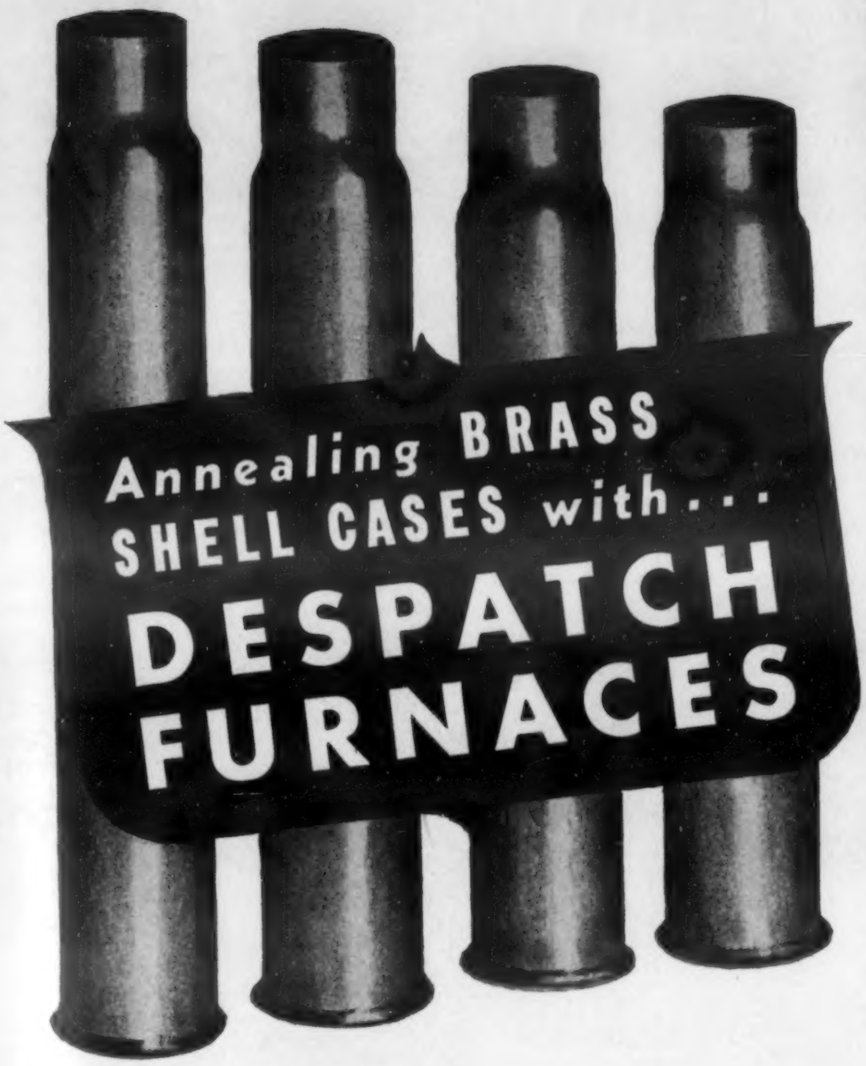
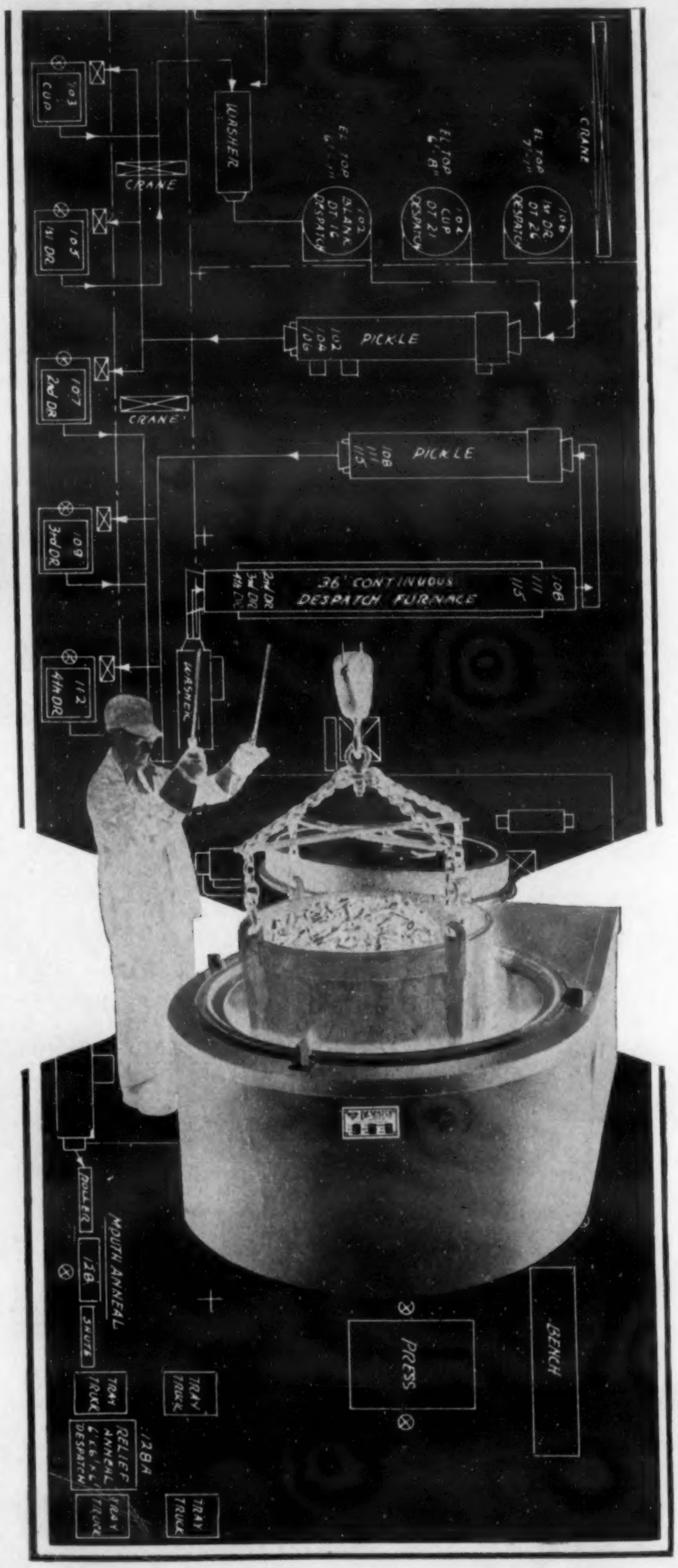


Annealing BRASS SHELL CASES with . . . DESPATCH FURNACES

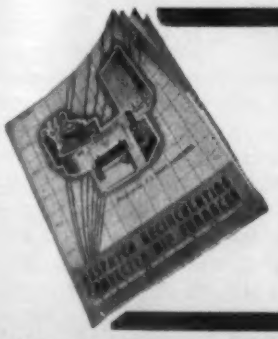

103 CUP
105 1st DR.
107 2nd DR
109 3rd DR
112 4th DR
CRANE
CRANE
CRANE
WASHER
EL TOP
102 BLANK DT 16 DESPATCH
EL TOP
104 CUP DT 21 DESPATCH
EL TOP
106 1st DR. DT 26 DESPATCH
102 104 106 PICKLE
108 111 115 PICKLE
2nd DR 3rd DR 4th DR
36' CONTINUOUS DESPATCH FURNACE
108 111 115
WASHER
MOUTH ANNEAL
128
RELIEF ANNEAL
128A
TRAY TRUCK
TRAY TRUCK
TRAY TRUCK
TRAY TRUCK
PRESS
BENCH

A Despatch system for heat treating 4300-20mm. shell cases per hour is shown at the right. It carries through from brass blanks—through draw presses and Despatch annealing furnaces—and finally through a Despatch stress relief furnace. The Despatch furnaces and other equipment arrangement provides material handling efficiency with minimum floor space. In this plant, Despatch furnaces were chosen because they provide speedy, accurate heat treating results together with increased production. Despatch furnaces are also performing perfectly for tempering and drawing of projectiles and shot, and on other armament projects where efficient, accurate heat treating in the range 275°F. to 1250°F. is required.

For those interested in the details of the layout illustrated, Despatch has available copies and will mail upon request. Whenever you require new heat treating equipment to increase your defense production, call a Despatch engineer to make a survey and submit his recommendations.

Despatch furnaces used in above layout for heat treating 4300—20mm. brass shell cases per hour.

1—Despatch DT-16 Pot Type Gas Fired Furnace, 1200°F.
1—Despatch DT-21 Pot Type Gas Fired Furnace, 1200°F.
1—Despatch DT-26 Pot Type Gas Fired Furnace, 1200°F.
1—Despatch Continuous Conveyor Annealing Furnace, 1200°F.
1—Despatch Stress Relief Furnace, 500°F.



WRITE FOR NEW BULLETIN NO. 81-E.

You will find it a helpful guide for heat treating ferrous and non-ferrous alloys with many interesting photographs of Despatch furnaces in action and with careful attention given to material handling.

DESPATCH

OVEN COMPANY MINNEAPOLIS, MINNESOTA

attention to the cleaning of the steel prior to plating or hot-dipping. Cleaning is difficult because of the wide diversity of foreign substances that may be present.

Electrolytic cleaning is the most important method of removing most of the oily materials, such as fats, oils, coolants, etc. Since anodic and cathodic cleaning give about the same result, the cleansing action probably results from the evolution of gas beneath the dirt film, which is thereby broken-up and dispersed.

In the cold rolling of steel, high pressures are required and much heat is generated. Coolants are used to carry away the heat and lubricate the metal. Annealing is required to remove the hardness resulting from the cold work. Steel annealed in an inert atmosphere and then hot-tinned without being cleaned, yields imperfect tin plate.

Removal of the coolant is difficult after annealing and must be done directly after the rolling. As the speed of cold rolling may be as high as 2,000 ft./min., the cleaning of continuous lengths for hot-tinning have raised special problems.

The process used consists in subjecting the strip to heavy jets of warm alkaline solution. The strip next enters an electrolytic cleaner of sodium meta- or orthosilicate, 2-5 oz./gal., in a tank 60 ft. long. The current density is 50-100 amps./sq. ft. and the temperature 200° F.

At the high speed of passage the strip is in the cleaner only about 3 sec. Rubber rolls and air jets are used to prevent excessive dragout. The strip next passes between revolving brushes, through a hot water dip, a hot air drier, and then is ready for annealing.

Current is carried to the steel either by special contacts, or without any metallic connections whatever by making the strip an intermediate electrode. Data are given on the consumption of electricity and chemicals.

The cleaning of steel for electroplating must be done more carefully than for hot tinning. The surface dirt on rolled steel depends to a large extent on the quality of the cold rolling. The coolant is decomposed during the rolling operation by the elevated temperatures which may be above 450° F. and leaves films on the steel which are difficult to remove. A presoaking in kerosene is helpful.

This is followed by a strongly alkaline cleaner containing 2-4 oz./gal. of sodium silicate and 8-10 oz./gal. of sodium hydroxide. A current density of 100 amps./ft.^{2} is used.

Combinations of oils produce more difficultly removable films than single oils. The general conclusions about baked-on films are confirmed by English investigators.

AB (2a)

Structures of Iron-Carbon Alloys

"Microstructural Characteristics of High-Purity Alloys of Iron and Carbon." Thomas G. Digges. *J. Res., Natl. Bur. Standards,* Vol. 27, July 1941, pp. 65-79. Investigation.

Seventeen irons, varying in degrees of purity, were carburized in a mixture of hydrogen and benzene vapor at 1700° F. for 3 hrs. followed by cooling in this atmosphere through the transformation range at 4°F./min. The time at the carburizing temperature was sufficient to produce hypereutectoid zones in all of the irons.

The presence of free ferrite in the hypereutectoid zones is characteristic of the structures obtained in irons of very high purity under these conditions. As the amounts of impurities in the irons are increased, the final structures obtained after carburizing may or may not contain free ferrite in the hypereutectoid zone, depending upon whether the added impurities are of the type which increase or decrease the reaction rate of austenite or the diffusivity of carbon in the Ar_1 transformation range.

Differences in oxygen content from about 0.001 to 0.007% could not be correlated with the amount of free ferrite in the final structure of the alloys. Some of the irons represent a close approximation to oxygen-free material. The precise role of oxygen in the development of ferrite in the final structure is not entirely clear. However, if oxygen were responsible for this structural feature in the hypereutectoid alloys of highest purity, then a minute amount was sufficient and as effective as larger amounts.

The carburized structures of all the irons that were free from aluminum contained free ferrite. Aluminum in excess of about 0.001% inhibits the formation of free ferrite in the hypereutectoid zone, and alumina was not the factor responsible for its formation.

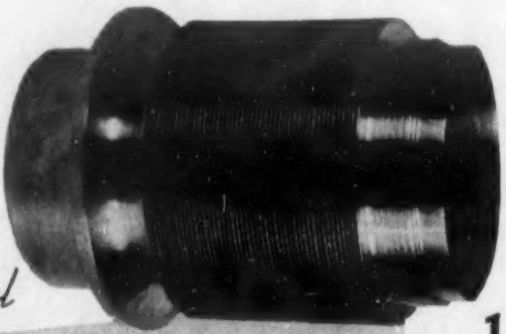
The presence of hydrogen in the carburizing and annealing atmospheres had no detectable effect on the formation of free ferrite. Free ferrite was not detected in the eutectoid zone of any of the alloys. However, variations might exist in amounts of proeutectoid carbide without markedly

Stuart's

Thred Kut

PAT'D U. S. PATENT OFFICE

America's Unique Alloy Steel Cutting Oil



1

WIDELY RECOGNIZED BY THE
AIRCRAFT ENGINE INDUSTRY
AS AN IMPORTANT WORKING TOOL
This is one of its Outstandingly Successful Applications

2

1. The finished cylinder barrel of a Wright Cyclone.

2. The cylinder barrel cut in two showing the depth and thickness of the cooling fins.

THE forty-six cooling fins on the cylinder barrel of a Wright Cyclone aircraft engine are cut in a single operation on a Fay automatic lathe. Using Stuart's THRED-KUT #99, these fins are cut cleanly to a depth of ⅝ in. and are only 0.022 in. thick. Seventeen pounds of metal are removed from this tough Nitralloy steel forging in twenty minutes.

• *When that TOUGH job comes along in YOUR plant —on ANY defense part—put Stuart's Thred-Kut and STUART OIL Engineering Application Service to work. Quit wishful thinking and GET the desired improvement quickly!*

SEND for the New 48 page Booklet "Stuart Oils — The Straight line to Metal Working Efficiency."

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For All Cutting Fluid Problems

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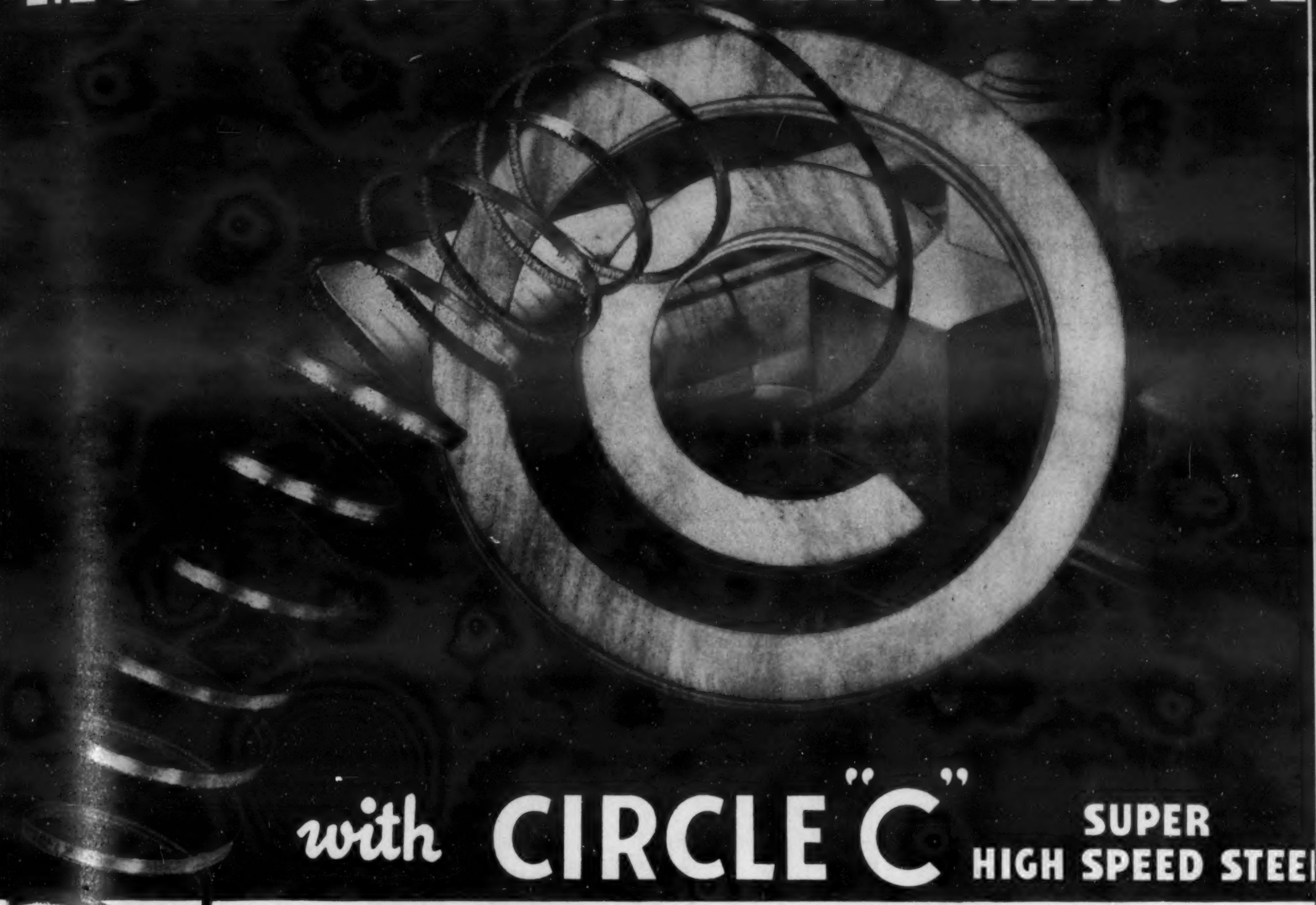
MORE CHIPS PER MINUTE



with CIRCLE "C" SUPER HIGH SPEED STEE

No matter what the unit of time—minute, hour, or day—the *true measure* of a cutting tool's effectiveness can be judged by the *net* amount of metal it removes in a given period.

CIRCLE "C" Cutting Tools are constantly demonstrating their capacity to work at 25% faster machine speeds, with greatly increased cuts and feeds and far fewer shutdowns for re-grinds on the hard and heat-treated alloys used in production of *shells, aeroplane engines and other armament.* Thus, this high cobalt-tungsten Super High Speed Steel, distinguished in a peace-time economy for its prodigious chip removing ability, now occupies a unique place among steels in Defense industries. *Although a tungsten steel it actually conserves tungsten through greater production as compared with other tungsten high speed steels.*

FIRTH-STERLING
STEEL COMPANY

OFFICE AND WORKS:
McKEESPORT, PA.
BRANCH WAREHOUSES:
NEW YORK CHICAGO
HARTFORD PHILADELPHIA
LOS ANGELES DAYTON
CLEVELAND DETROIT

affecting the formation of free ferrite on slowly cooling from the austenitic condition.

Free ferrite in hypereutectoid alloys was produced with equal facility either by cooling directly from the carburizing temperature or by annealing *in vacuo*. The initial structures of the irons, either as cast or after working had no effect on the formation of free ferrite in the final structures.

The average grain size established in carburizing the various irons at 1700° F. ranged from A.S.T.M. grain number 4 to —1, but there existed no correlation between austenitic grain size and the formation of free ferrite. A noteworthy feature was the large austenitic grains of the alloys of highest purity, which contained relatively large amounts of free ferrite.
WAT (2a)

Forging Guns

"Forging Guns at Titusville." Arthur F. Macconochie (Univ. Va.) *Steel*, Vol. 109, Aug. 25, 1941, pp. 54-56, 58, 60, 82. Descriptive.

The manufacture of 37 mm. and larger size gun forgings at Struthers Wells Titusville Corp., Titusville, Pa. is interesting.

Ingots of highest quality electric alloy steel are purchased. They are prewarmed in a water bath to 200° F. and then transferred to a preheating furnace where the temperature is raised to 1200° F. One hr./in. ingot diameter is allowed. The ingot is then transferred to a heating furnace where its temperature is raised to 2000°-2100° F., care being taken to soak thoroughly.

The ingot is reduced to a billet of square section in a hydraulic press. Then 30% of the top and 5-10% of the bottom of he billet are removed. For 37 mm. guns, the billet is worked down to form under a hammer after reheating to 2100° F. A press is used for larger sizes.

During this operation, the temperature is allowed to fall to 1500°-1600° F. The forging is immediately buried in a steel box containing fuller's earth, where it is cooled to 150° F. in 7-12 days. Mica, ashes or similar materials would serve equally well. Experience has shown that if this very slow cooling is omitted, checking of the steel occurs.

The forging is then given a double normalizing by heating slowly in a vertical gas-fired furnace and holding at 1850° F. for 8 hrs., cooling in still air to 500° F., recharging and heating to 1650° F., holding for 6 hrs., and air cooling. For quenching, the forging is reheated to 1550° F., held for 6 hrs., lowered into an oil bath, and removed at about 300° F.

This is followed by a draw at 1050°-1150° F., holding time being 10 hrs. The tubes are straightened under a hydraulic press and are then returned to the furnace where they are heated and held at a temperature 100° F. less than the draw temperature.

Longitudinal and transverse test specimens are secured and physical tests made. The test procedure outlined in Federal Specification QQ-M-151o is followed for determining yield strength.

The company does its own machining on barrels. Larger calibers are rough-turned and bored prior to quenching to permit quenching oil to enter center of piece.
MS (2a)

Sulphurized Cutting Oils

"A Study of Cutting Oils with and without Added Sulphur." O. W. Boston & J. C. Zimmer (Univ. of Mich.) *Am. Soc. Metals*, Oct. 1941 meeting, Preprint No. 8, 17 pp. Investigation.

Five oils were used in a study of effects on performance of cutting oils with and without added sulphur. These oils were designated as A, B, A_s, B_s and A + s.

Oil A contained 0.10% sulphur in its natural state, while oil B contained 2.03% naturally occurring sulphur. Oils A_s and B_s were sulphurized products, using the base oils A and B, respectively. The fifth oil, A +s, was prepared by simply adding 1.6% of an oil-soluble, synthetic sulphur compound to the 0.1% natural sulphur content at 100° F., and mixing thoroughly.

The tests run with these oils were tool-life cutting-speed tests, drilling tests, and lubrication tests. In conjunction with these various experiments, the power required in turning was determined and the chip formation studied.

The test log used in the cutting-speed tool-life tests was a forging with an analysis to conform to an S.A.E. 3140 steel. The log was normalized and annealed; the tensile strength was 96,000 lbs./in.^{2}; the Brinell hardness was 207. The tools used were of the 18-4-1 type of high speed steel. Tool life was indicated by the complete breakdown of the tool.

In the drilling tests, 4 different steels were used: the S.A.E. 3140 steel, same as used for the cutting-speed tool-life tests; annealed S.A.E. 1020; annealed S.A.E. 1035; and cold drawn S.A.E. 1112.

From the tests the following conclusions were reached: In determining the tool-life cutting-speed relationship, a straight line on log-log paper is obtained for each of the 5 oils and for cutting dry. The plots have equations of the type $VT^n = C$, where V is the cutting speed, T is the time for total

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Just one generation ago the Management of a Pennsylvania company manufacturing steel oxygen cylinders was very proud of the above semi-automatic blast cleaning installation. It cleaned their entire production of various sized work in a new record time for the industry.

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The Army, Navy and Air Force, require great supplies of oxygen. All planes that fly at high altitudes provide oxygen through breathing masks to crew members in order to sustain life in the stratosphere.

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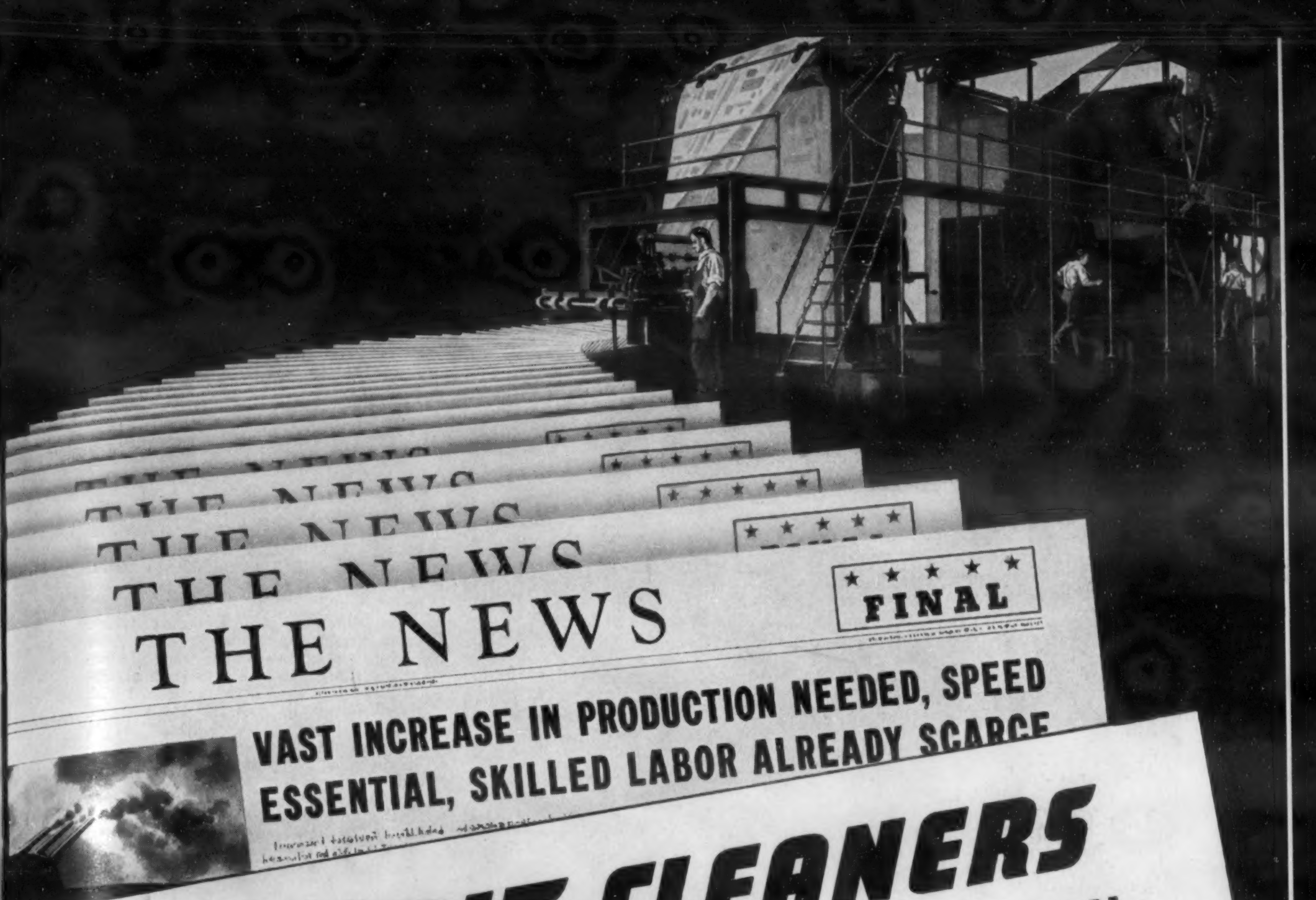
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help speed defense production . . . SAVE MEN

A prominent automobile manufacturer has achieved these four striking advantages in cleaning metal parts by switching from hand cleaning with tools, brushes and a solvent to the use of a special cleaning machine containing a solution of a Pennsalt Cleaner:

1. A substantial saving in man hours of cleaning time . . . 8 men, with a Pennsalt Cleaner solution in a special cleaning machine, accomplish what 75 men did manually before.
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In many manufacturing plants all over the country, production is being speeded by the use of Pennsalt Cleaners . . . in some cases, to shorten each step in the metal cleaning cycle . . . in others, to eliminate whole operations by cleaning several metals with one Pennsalt Cleaner.

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tool failure, n represents the slope of the line from the horizontal, and C represents the vertical displacement of the line for a tool life of 1 min.

By thermally sulphurizing the oil B with high inactive sulphur to give oil B_s, the performance factor is increased from the poorest to the best, at 5.1% increase, and the tool life is increased 78%. In the comparison of A to A_s, performance C is increased 2.2%; tool life is increased 31%. Comparing A to A + s, the speed is increased 3.3%, and the tool life 47%. The increase in speed of the best oil B_s over that cutting dry is 5.5%, while tool life increased 485%.

The added active sulphur content values did not correlate with the relative cutting performance of the sulphurized oils.

High natural sulphur does not give high cutting performance, but seems to aid sulphurization to give a superior product. All tools failed in turning by the usual cupping process. All oils caused the chips to be formed in a normal way, and the chips broke up into small pieces in a shorter time with the oils than when turning dry.

The drilling torque in S.A.E. 3140 steel is highest for cutting dry, reduced for plain oils A and B, and reduced further for the sulphurized oils. The drilling thrust is highest for cutting dry and lowest for the plain oil A. Torque and thrust values obtained for various oils in one steel do not necessarily have the same relation in another steel.

Oils containing high active sulphur showed a high load carrying capacity. A low capacity was found for those oils with low active sulphur. The shock loading test seems to give the best correlation with cutting speed performance of the oils.

(2a)

2b. Non-Ferrous

Annealing Aluminum-Silicon Alloys

STRUCTURAL CHANGES IN ANNEALING ALUMINUM-SILICON ALLOYS ("Ueber die beim Glühen von Al-Si-Legierungen eintretenden Gefügeveränderungen) H. RÖHRIG & E. KAPERNICK. *Aluminium,* Vol. 23, May 1941, pp. 235-239. Research.

A study was made of changes of the form of the structural constituents of an alloy during the heat treatment. Such changes occur more easily with greater solubility of the precipitated constituent in the base metal.

Six different aluminum-silicon alloys (with 9-13% Si and various iron, manganese, copper, magnesium and titanium contents) were melted in a graphite crucible and heated to 1475° F., treated with aluminum fluoride, cooled to 1375° F. and cast in disks of 2¼-3¼ in. diam. and ¾ in. thickness. No significantly different behavior in the progress of formation of precipitated constituents could be established.

The first changes occur at 1020° F. after a few minutes of heating. In both the heat-treated and the not-heat-treated condition the size of the precipitates increases and their number decreases with time.

The formation of silicon, which is much more soluble in aluminum than the aluminum-iron-manganese compound, starts much earlier than that of the latter compound.

Ha (2b)

Finishing Light-Metal Castings

"WEATHERPROOFED FOR THE CLOUDS." H. E. LINSLEY (Wright Aeronautical Corp.) *Am. Machinist,* Vol. 85, Sept. 17, 1941, pp. 907-909. Practical.

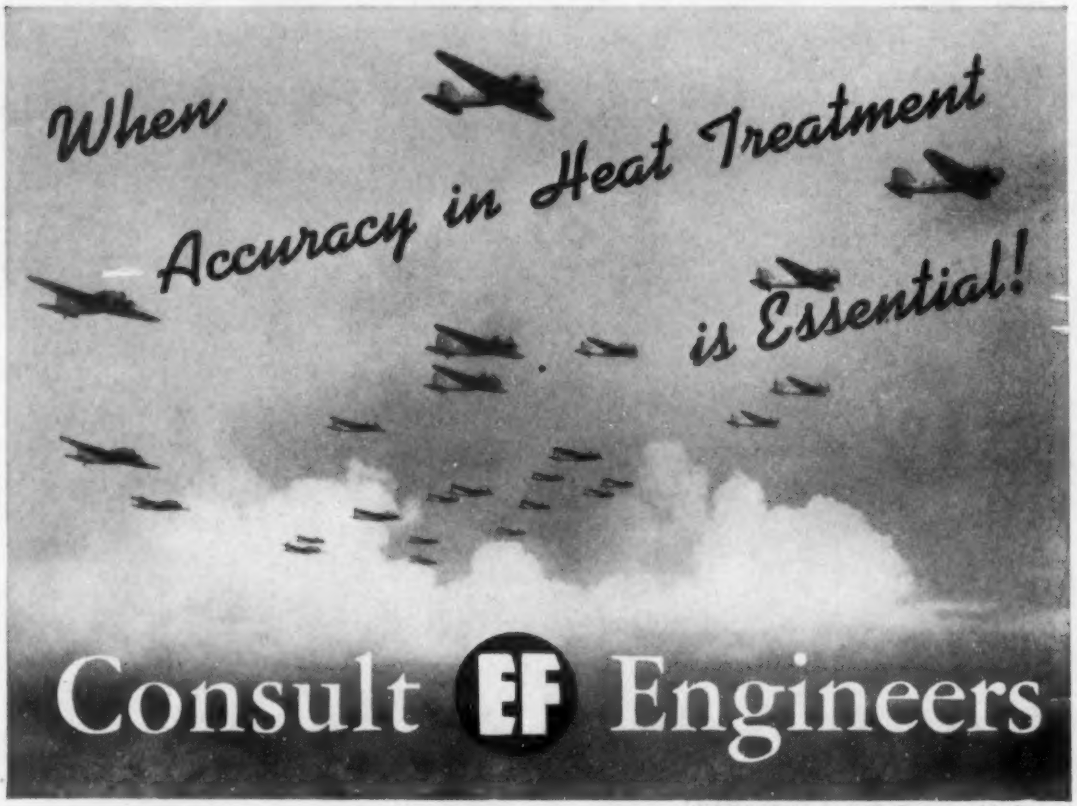
Magnesium alloy castings used for exposed parts of aircraft engines are dipped in a solution of sodium dichromate in nitric acid and rinsed in hot water before they leave the foundry. After the final machining operation, the part is thoroughly cleaned in hot water and in a vapor degreaser.

Then the articles are immersed for 5 min. in a lead-lined tank containing 10-15% hydrofluoric acid to remove all oxides and etch the parts. After a rinsing in cold water, the parts are placed for 45 min. in 10% sodium dichromate at 210° F., rinsed in cold water, dipped in boiling water, and finally thoroughly dried with an air blast.

Pressure sprays are used to clean out blind holes, while operators must wear rubber gloves to avoid finger marks on the parts. If the magnesium is to be on the outside of the engine, it must also receive a coat of paint. If it is to have a steel insert, it is given a coat of baked zinc chromate primer before it is returned to the machine shop.

Aluminum alloy parts are also thoroughly washed, but then anodized in 3-9% chromic acid at 92°-99° F. for 30 min. Subsequently these parts are rinsed, dried, and painted.

JZB (2b)



"Official photograph U. S. Army Air Corps"

WHILE uniformity is desirable in any heat treating operation, accuracy is vitally important and an absolute necessity in the aircraft industry.

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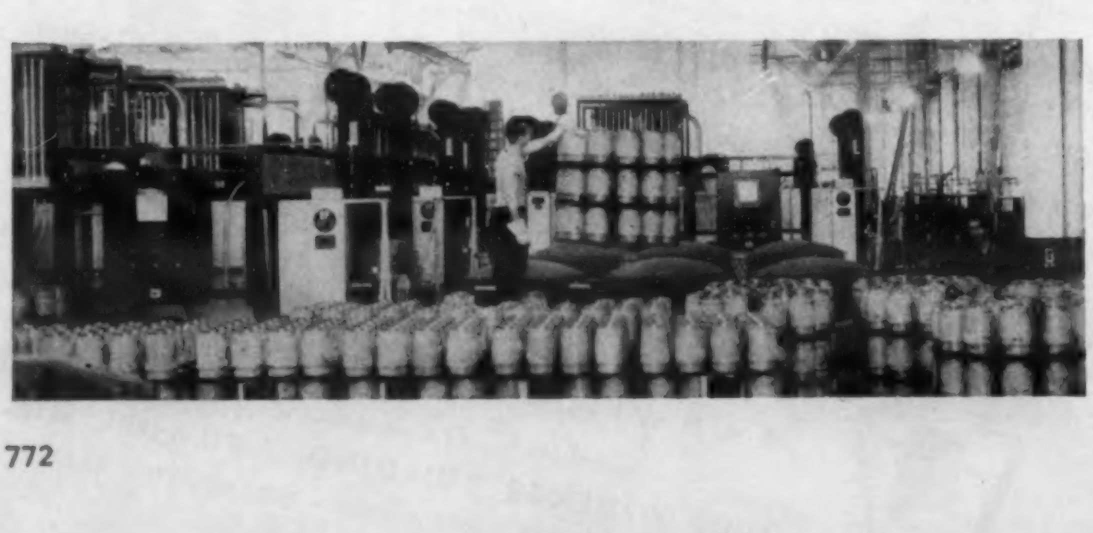

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Deep Drawing Magnesium Sheet

"Deep Drawing and Pressing of Magnesium Alloy Sheet." R. G. Wilkinson & D. B. Winder. *Sheet Metal Inds.*, Vol. 15, Aug. 1941, pp. 1039-1042. Practical.

Standard sheet magnesium alloy for deep drawing is Elektron A.M. 503 (1.5-2% Mn). Most of the manganese is in solid solution, while free manganese particles are not in stringer formation. Manganese represses critical strain grain growth.

Mechanical properties are independent of heat treatment unless the alloy is greatly overheated. Below 435° F. deformation can take place by slip only along the basal planes of the close-packed hexagonal lattice structure, but above 435° F. additional slip planes come into play. Consequently, deep drawing is conducted at 500°-750° F. at such a speed that recrystallization takes place simultaneously with deformation.

Because the deep drawing is conducted at elevated temperatures, sheet of very small grain size may be used (although this usually means low malleability at room temperatures) with a resultant excellent surface finish. The Elektron A.M. 503 alloy shows a small amount of preferred orientation at room temperature, but this directionality is very greatly reduced at working temperatures.

It is always supplied in the chromated condition, which gives an ideal surface for drawing. Only 2 tests are believed necessary for routine examination: metallographic—to determine average grain size, uniformity of grain size, presence or absence of second phase, and amount and distribution of free manganese; and actual drawing tests, either on a production press or on a special miniature press.

The principal advantages of working at an elevated temperature are that a very severe reduction can be made in a single draw (such as 60%) and that spring back is eliminated. For shallow draws electrically heated steel female dies are used with a rubber male forming element. In the United States it has often been found more economical to use steel male and female dies where both dies contain heating elements and preheating of the blanks is unnecessary. A temperature of 300°-400° F. is adequate for shallow draws, but 500°-750° F. is required for deep drawing proper.

Deep drawing is conducted as usual with a punch, female die, and pressure pad. The punch is usually not heated; but the pressure pad and female die must be heated (gas heating is usually cheapest). The punch may be of steel or aluminum and need not be polished or lubricated. Sliding surfaces of the draw ring and pressure pad should be polished and lubricated with a 20% solution of graphite in tallow; the blank should also be lubricated on both sides with the same lubricant.

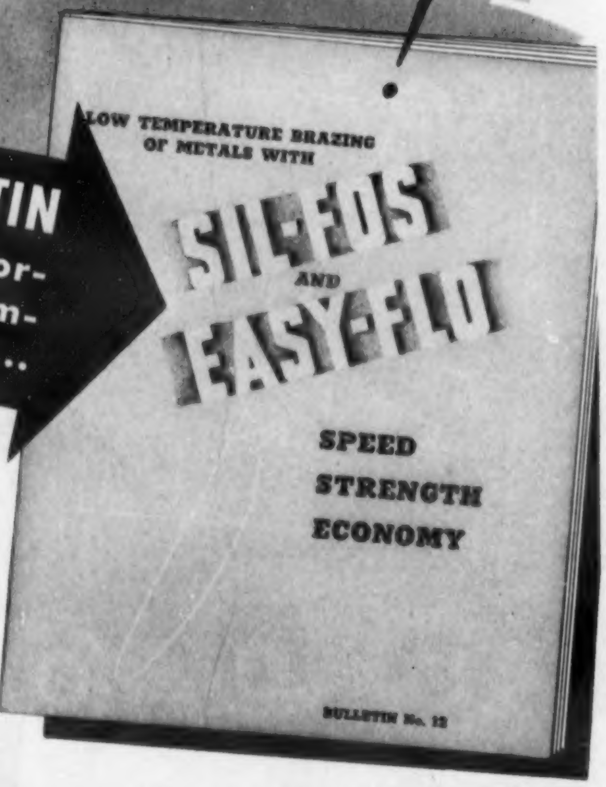
The most usual stroke speed for hydraulic press work is 15 ft./min. After the sheet has been formed, it should be dipped in hot 15% chromic acid to remove the lubricant.

In general, magnesium alloy is advantageously used for selected components of fuselage, wings, as well as internal equipment, ammunition and flare boxes, wing tips and fillets, cowlings, fuel and oil tanks, etc. The use of magnesium alloy in gages thinner than 22 is not recommended unless fatigue stress in service is very low. However, magnesium alloy has excellent welding properties in gages such as 20-14.

JZB (2b)

NOW READY FOR YOU!

THIS NEW BULLETIN
It gives complete information about low temperature brazing with...



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Anodizing Aircraft Parts

A Composite

Sulphuric acid baths for the anodic oxidation of aluminum and its alloys enjoy a much broader application in this country than the chromic acid bath—the sulphuric process can be used on a wider range of alloys, is more "versatile" generally, and is often cheaper or faster. But in the aircraft industry, the quality of the coating produced in the chromic acid bath is such as to make it the favorite for aluminum and aluminum alloy aircraft parts.

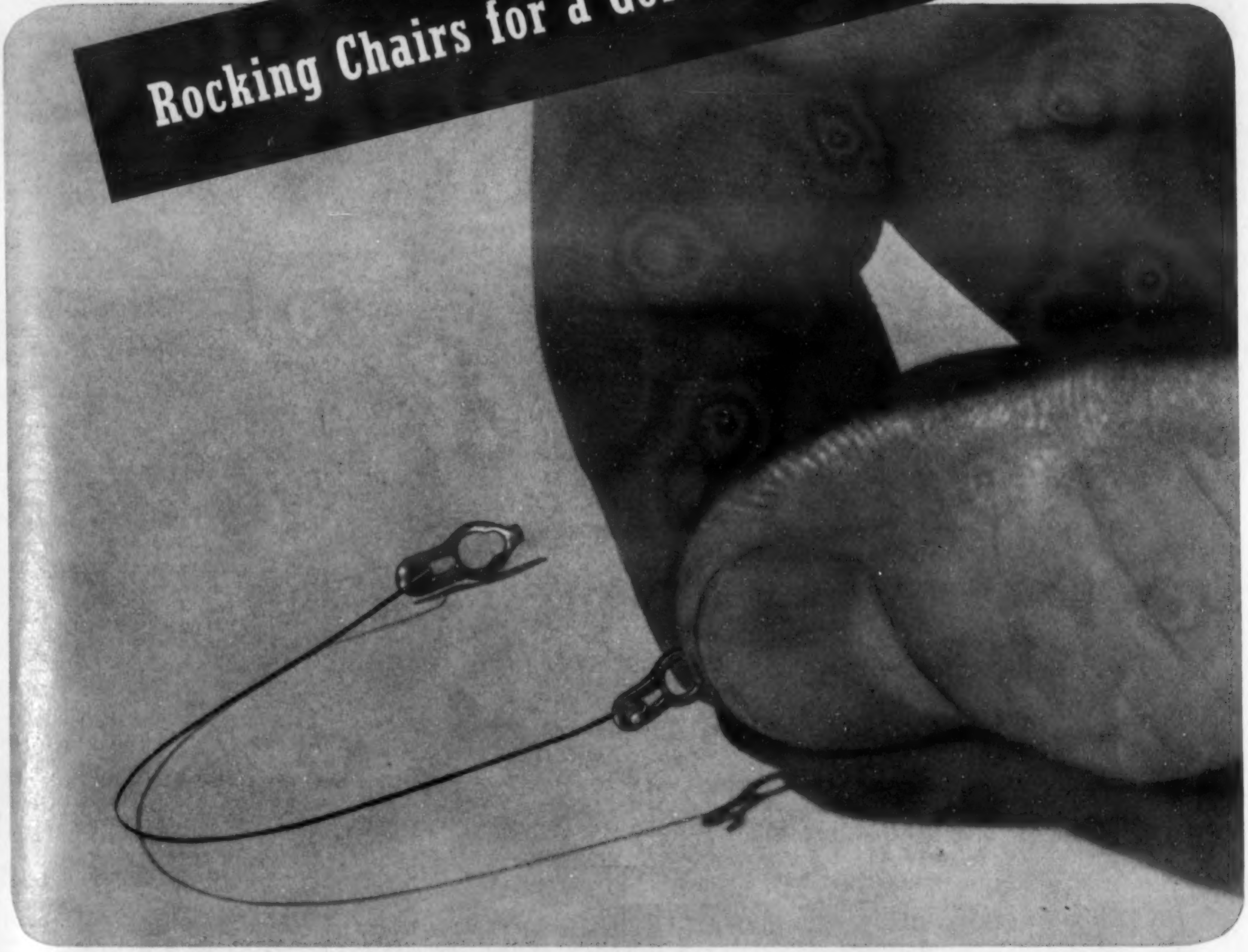
Practice in two American aircraft plants using the chromic acid process, and some "kinks" adopted by a British manufacturer to speed up his chromic acid anodizing, have been described in recent articles.

American Practice

The anodizing of aluminum parts is required on all exposed surfaces of naval aircraft and on a smaller number of parts for army and commercial land planes, and for such work the chromic acid electrolyte has been adopted by the majority of aircraft companies in the United States, reports Manuel Sanz of Vultee Aircraft, Inc. ("Chromic Acid Baths for Anodizing or Chromatizing Aluminum or its Alloys," *Mo. Review Am. Electroplaters' Soc.*, Vol. 28, Sept. 1941, pp. 709-717). Government specifications permit other processes to be used, but require that anodized specimens withstand 720 hrs. of salt spray.

The importance of the oxide film lies in its resistance to abrasion and the adherence offered for paint. The chromic acid proc-

Rocking Chairs for a Gold "Whisker"!



TIME was, when all pyrometer galvanometer suspensions were merely wisps of ordinary metal held in crude soldered end-clamps. Acid atmosphere ate the metal . . . ends sheared off on the square edges of clamps . . . breakage was accepted as a necessary evil.

Even though it is the smallest, least conspicuous assembly in a Foxboro Potentiometer Instrument, Foxboro engineers were not content with this traditional galvanometer suspension. They engineered this detail, too, like a major part!

Gold suspensions were adopted to defy acids . . . with spot-welded instead of soldered ends. Smoothly-crowned end-brackets were designed, to give shear-free, "rocking-chair" snubbing action for these tiny gold "whiskers". Suspension life was indefinitely prolonged!

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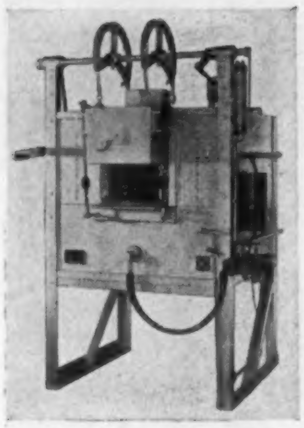
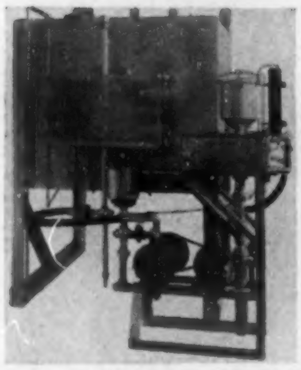


STANDARD CURTAIN TYPE

By far the largest proportion of "Certain Curtain" furnaces are of the Standard Curtain Control type, which meets the requirements of most plants for tool and die preheating and hardening. This is the basic "Certain Curtain" design using a curtain of precombusted gases to seal and fill the heating chamber with protective atmosphere. Wide variation in the composition of the atmosphere is possible and the desired atmosphere can be duplicated and maintained precisely.



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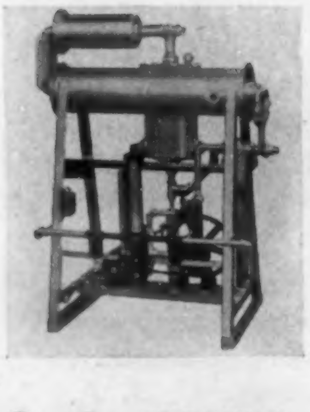
Especially applicable to Moly steels, The Recirculator method of controlling furnace atmosphere enables high molybdenum steels to be hardened without decarburization, and is also used when it is desired to harden carbon and alloy steels with a bright, or "super", finish. The condensing and purifying action increases CO and decreases CO_2, giving an atmosphere which will not decarburize any steel at any temperature.



EXTERNAL GENERATOR TYPE

The External Atmosphere Generator produces any required volume of precombusted atmosphere. It is used where it is impractical to introduce atmosphere into the furnace by the curtain method; and also as a supplementary supply where the volume of atmosphere gases required is greater than the regular precombustion chamber can produce. Atmospheres produced by the External Generator can be varied, duplicated and consistently maintained, as with the Curtain method.

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ess consists in a 30 min. treatment at a potential of 40 volts in a 5-10% solution of CrO_3 heated to 95° ± 4° F.

The chromic acid bath deteriorates with use, through reduction of CrO_3 at the cathode and solution of aluminum. Reduction of CrO_3 can be prevented by using a larger anode area than cathode area. A method of regenerating a CrO_3 bath consists in using lead anodes, with an area equal to the cathode, and running the tank at a low voltage.

Lockheed Aircraft Corp.'s chromic acid anodizing practice described by PAUL P. MOZLEY ("Anodizing Aircraft Parts," *Products Finishing*, Vol. 5, June 5, 1941, pp. 34-52), is featured by a more dilute bath (under 5% acid) than is customary.

A simple theory of the anodizing process using a chromic acid bath is that the chromic acid radical is attracted to the aluminum, losing part of its oxygen to form the oxide film. The acids present will be both chromic and dichromic and will be capable of reacting with the aluminum oxide that has been formed. The acid concentration will determine the rate at which this re-solution occurs.

Proper concentrations are, therefore, such that the dissolving action should be sufficient to produce small pores through which the contact between the aluminum and electrolyte may be maintained without excessive removal of the oxide layer. This will result in building up the oxide layer. Concentrations of 1.5-3.0% acid produce films of desirable density with a current density of one amp./ft^2 of area being anodized.

After a period of use any chromic acid solution ceases to function when the current density has gradually dropped to 0.9 amps./ft.^{2}, and additions of acid are necessary to obtain satisfactory results.

At the Lockheed plant several factors led to the decision that operating below 5% acid was desirable: Among these are (1) ability to carry loads of large area without increased generator capacity, (2) reduced acid consumption, (3) uniformity of results, and (4) recognition that a thin nonporous coat was desirable for paint adhesion.

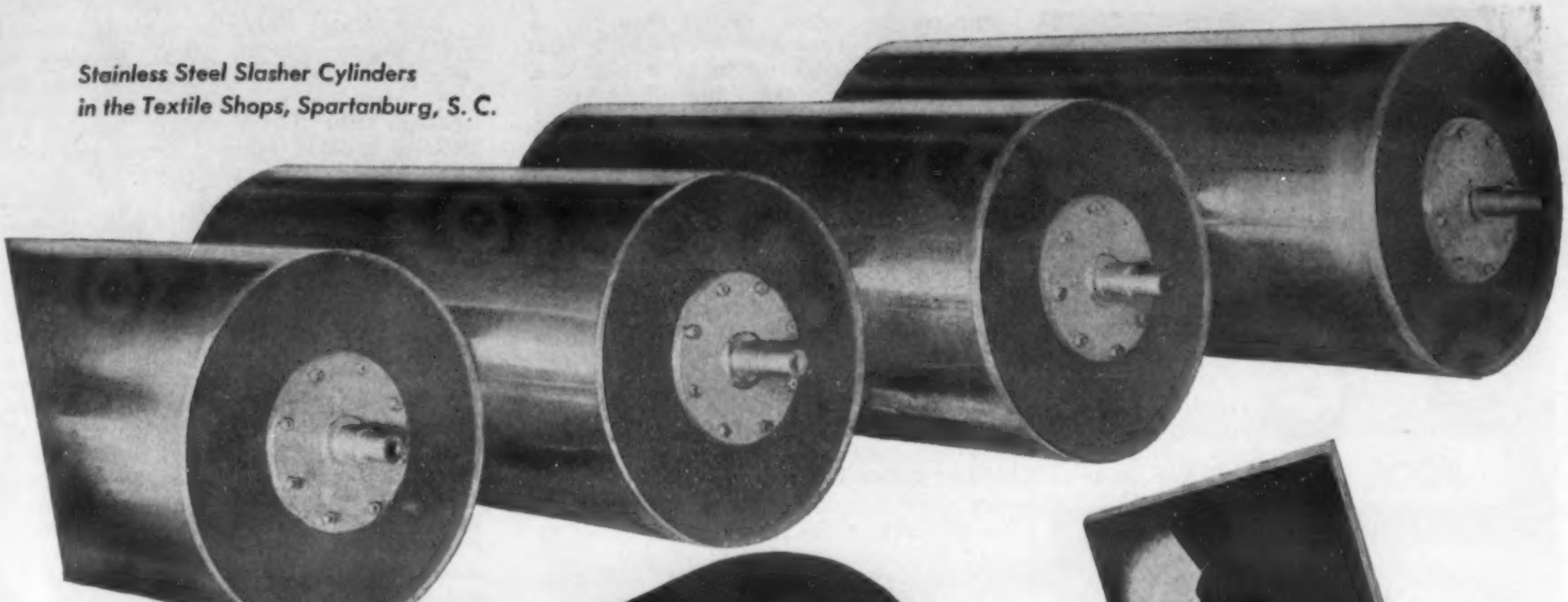
Control of the bath concentration is best done by starting with a concentration of chromic acid of 1.5 gm./100 cc. of water plus whatever excess quantity of acid is decided as the most convenient quantity for regular additions, and adding acid at the rate of 100 lbs. per each 35,400 amp.-hrs. of use as measured by an amp.-hr. meter. When the acid has reached a concentration of 10-11 gm./100 cc. of total chromium calculated as CrO_3, discard the solution and start a fresh one. The figure of 35,400 amp.-hrs. was reached on the basis of efficiency tests conducted on the solutions.

British Practice

The first widely used chromic acid process (the Bengough-Stuart method) of anodizing aluminum originated in England, hence British experience should be significant. Practical hints on increasing anodizing output over 25% per operating hour are given in one article ("How a Works Manager Increased his Output of Anodically Oxidized Aluminum," *Sheet Metal Inds.*, Vol. 15, Mar. 1941, pp. 367-370), including operation of baths at *higher* acidity than normal.

With chromic acid solution, there are 3 main ways of obtaining an increased yield: The first is altering the anodizing conditions while using the standard solution. The Bengough-Stuart method specifies 104° F. ± 8° F. with the voltage gradually increased to 50 to give 3 amps./ft.^{2}; the total treatment time is 1 hr. Treatment

Stainless Steel Slasher Cylinders in the Textile Shops, Spartanburg, S. C.



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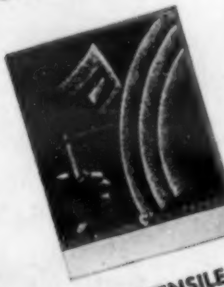

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time can be reduced to less than 2/3 of standard by using 93° F. ± 2° F. and raising the voltage to 60 in 7 min. and maintaining it for 28-30 min.

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The second method of increasing output is by altering the solution. Instead of the normal 3% chromic acid solution, a 10% solution can be used at 95° F. ± 4° F. with 30-40 volts and 3 amps./ft.^{2} A film as thick as the standard can be produced in 34-40 min. Also, the treatment can be used as a batch operation or continuously.

A third possibility involves increasing the efficiency of the plant and personnel by more accurate controls and records. The solution analysis should be checked daily to see that the chromic acid content does not decrease below 2.5%, and that the impurity content is not too high. Copper and silicon are especially deleterious, while the use of water that has not been distilled may lead to trouble with pitting due to chlorine and sulphate ions. X (2b)

Soft Soldering

"The Art of Soft Soldering." A. J. T. Eyles. *Sheet Metal Inds.*, Vol. 15, Sept. 1941, pp. 1166-1168. Practical.

Electric furnaces for heating soldering tools have the advantages of rapid and uniform heating, and produce no pitting of tools. However, modern gas-fired furnaces are very economical if the work is continuous.

Forged soldering tools made from electrolytic or selected copper drawn bars are better heat retainers and are less likely to crack than such tools cast from ingots. Recommended soft solders and fluxes for various sheet metals are given in the Table.

JZB (2)

Sheet Metal to be Soldered	Flux	Composition of Solder, %		
		Sn	Pb	Bi
Aluminum	Stearin	95	..	5
Brass	Zinc chloride or resin	67	33	..
Copper	Zinc chloride or resin	67	33	..
Galvanized Iron	Dilute hydrochloric acid	50	50	..
Lead	Resin or tallow	33	67	..
Monel, Nickel	Zinc chloride	66	34	..
Pewter	Resin, tallow or olive oil	25	25	50
Silver	Zinc chloride	70	30	..
Stainless Steel	HCl and Zn chloride (1:1)	55	45	..
Terne Steel	Zinc chloride	50	50	..
Tinned Steel	Zinc chloride	55	45	..
Zinc	Dilute HCl or Zn chloride	50	50	..

Atmospheres for Non-ferrous Heating

"Atmosphere Control in the Heat Treatment of Non-Ferrous Metals." "Rova." *Sheet Metal Inds.*, Vol. 15, Aug. 1941, pp. 1007-1012. Review.

Aluminum and its alloys present fewer problems in heat treatment than any other non-ferrous material due to the protection afforded by the ever-present oxide film; consequently, special atmospheres are usually not necessary. Atmosphere also plays little part in the heat treatment of magnesium alloys because the temperatures are relatively low and the metal is protected to some extent by the natural oxide film or by artificial chromate films. Very occasionally it may be necessary to make an addition of sulphur dioxide to the air, but this is usually not required.

Even though the oxide is easily removed from copper and its alloys, reducing or special atmospheres are generally used today. Hydrogen is deleterious if the copper contains over 0.01% oxygen because the reaction product (steam) causes embrittlement at the grain boundaries. If the atmosphere is oxidizing, even so-called "OFHC" may show the same embrittlement as a result of oxygen penetration along the grain boundaries, followed by reaction with hydrogen.

Sulphur in all forms must be avoided owing to the rapid formation of black copper sulphides. Any oil or grease present on the copper should be removed before heat treatment as otherwise it will crack, giving a carbon deposit that is hard to remove. Steam or nitrogen is a suitable atmosphere for copper containing oxygen; city gas (partially burned or raw), cracked ammonia, hydrogen, or other reducing atmospheres may be used for oxygen-free metal.

Brasses are difficult to anneal free from tarnish. Most "controlled atmospheres" are suitable; water vapor is frequently employed. Open flame annealing causes "red stain" or local enrichment in copper. Sulphur is not very important, but traces of chlorine or its compounds cause a very rapid increase in oxidation rates. Small amounts of nickel or arsenic have no effect on "red stain" but antimony prevents it.

Aluminum and silicon, even in small amounts, reduce oxidation. Tin bronzes present no special problems. Silicon bronzes should be treated like the brasses or the pure metal. Aluminum bronzes are well protected by a film rich in aluminum oxide so no particular precautions are necessary unless they are to be subsequently drawn or pressed. In the latter case, bright annealing should be carried out to prevent abrasive action of the oxide film on the tools.

Sulphur and its compounds are the main factors to be avoided in heat treating nickel and its alloys, as sulphides are formed along the grain boundaries at temperatures as low as 1100° F. with subsequent embrittlement. Aluminum and silicon improve resistance to sulphur attack, while Inconel is superior to nickel and Monel in this respect. Moreover, scale removal may be difficult with alloys such as Inconel.

These materials require a particularly pure, reducing atmosphere, such as *dry* hydrogen. If complete freedom from oxidation is not required for Inconel, the same furnace atmospheres can be used as for Monel and nickel—carbon monoxide at least 2%, and no sulphur. Pot annealing and salt bath heating can also be used, but no sulphates or other sulphur compounds should be present in the salt.

Sulphur is also very harmful to silver.

The oxide formed on silver is perceptible at 400° F, but it decomposes at less than 575° F.

Platinum should not be subjected to prolonged heating in reducing atmospheres; some of its alloys are darkened under oxidizing conditions, but this oxide usually disappears as heating continues for a longer time or at a higher temperature. Tantalum oxidizes readily and must be protected during heating. Palladium oxidizes appreciably in air even at low temperatures, but cannot be heated in hydrogen as it absorbs this gas very readily. JZB (2b)

Silver Coatings on Non-Metals

"SILVER COATINGS ON NON-METALLIC SURFACES." J. R. I. HEPBURN. *J. Electrodepositors' Tech. Soc.*, Vol. 17, 1941, pp. 1-10. Practical.

The silvering of glass and other nonconductors affords a starting point for the electro-metallizing of non-metallic surfaces. At present graphite and bronze powder are commonly used.

Electrodeposition of copper over silvered glass is used for backing up the silver coating of mirrors, for strengthening glass vessels and for electroforming metallic mirrors, the latter being subsequently stripped from the glass mold. The advantages of silvering, as compared with graphite or bronze, is that the silver coating uniformly coats objects and renders the entire surface conducting.

Three formulas for silvering are discussed: the cane sugar formula (Brashear); the formaldehyde formula; and the Rochelle salt formula.

The author emphasizes the importance of priming the surface, before silvering, with a -10% solution of Stannous chloride which is subsequently rinsed off. The Stannous chloride adsorbed on the surface produces silver nuclei by reduction, which initiate the silvering process.

The Rochelle salt formula is usually used hot, but if the priming solution is used before silvering, the operation can be conducted in the cold. A freshly silvered surface can be immersed in a fresh silvering solution to receive a thicker deposit.

The thickness of silver deposited during the first min. is about 0.000,001 in. After 10 min. the thickness is about 0.000,006 in. and does not further increase. To provide better adhesion to a subsequently applied electrodeposit, the silvered surface is "quicked" by dipping in a dilute mercurous cyanide solution. AB (2b)

Aluminum Welding Fluxes

"PROGRESS IN RESEARCH AND CONTROL." *Light Metals*, Vol. 4, Aug. 1941, pp. 166-168. Review.

The fluxes used in the welding of aluminum have been the results of empiricism, and published investigations have dealt with the subject in a very incomplete manner. No one until recently appears to have attempted a rational examination of the salts commonly used in such mixtures from the standpoint of the specific effect of component compounds or the relative value of different mixtures.

Flux Requirements

It is of course established that mixtures of alkali chlorides and fluorides appear to serve the purpose quite well and indeed there is no evidence to date that as a class, such fluxes can be improved upon.

The properties that have to be considered are melting point, specific gravity, solvent power for aluminum oxide and other metallic oxides, viscosity, surface tension, porosity of flux layer, and its permeability to gases, vapor pressure at welding temperature, the effect of solution in it of metallic oxides, its heat insulating properties, its reaction with the molten metal, the possibility of using it as a source of alloying elements, possible use as a protective atmosphere, arc stabilizing properties, cost, and ability to be stored.

While it has been said that certain fluxes should be used with specified alloys, there is apparently no rational basis for such statements. The necessity for washing off fluxes from welded joints is emphasized time and again, but here again no published information appears to be available regarding the comparative corrodibility of fluxes, or the damage done in specified cases. Many reactions are supposed to occur leading to the formation of aluminum fluoride, hydrofluoric acid, hydrochloric acid, cryolite, etc., but apparently most of this is speculation.

Tests of Prepared Fluxes

A number of proprietary fluxes were analyzed and made up, and others were compounded according to patent specifications. Properties investigated included melting point, hygroscopicity, spreading power, solubility of aluminum oxide, the effect of flux on the surface tension of molten aluminum.

Altogether 12 commercial flux mixtures were examined and 40 fluxes were made

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from patents. Melting points varied from 1000° F. to over 1500° F., with many about 1100°-1200° F.

Hygroscopicity was determined by exposing weighed samples to the atmosphere and determining the water absorbed. Most of the fluxes were hygroscopic, due chiefly to lithium chloride, and in a few cases magnesium chloride. There was some evidence that water absorption could be somewhat reduced by the presence of non-hygroscopic salts.

The spreading power was measured by heating a weighed amount of flux on an aluminum surface to 1140° F., or 1185° F., for the higher melting fluxes, for 16 and 25 min. respectively. Differences were observed, but no simple relation was discovered between composition and spreading power.

It was further observed that the spreading power was influenced by the type of surface of rolled aluminum. The tests were therefore carried out on specimens treated by anodic oxidation (Bengough-Stuart process).

The influence of the fluxes upon surface tension was investigated by melting a small cylinder of aluminum with an equal volume of flux, on a 14% Cr stainless steel disk. The surface tension was estimated by the geometry of the melted and frozen aluminum. However, these tests left much to be desired inasmuch as they were clearly dependent upon the ease with which the flux removed the oxide film from the steel.

Alumina Solubility

Perhaps the results of the alumina solubility tests were the most interesting. It is to be expected that the solubility would be considerably affected by the form of the alumina. The latter undergoes a crystallographic change on being heated to about 1560° F. and becomes less soluble and less attacked by reagents. The alumina used was prepared by the reaction of mercury on super-purity aluminum and was a light, porous modification.

The alumina thus prepared was heated for 15 min. at 1100° F. in a gas muffle furnace before use. The experiments were conducted by melting 10 g. of flux in a nickel crucible in an electric furnace at 1200° F. After it had become liquid, about 0.2 g. of the prepared alumina was added. The mixture was allowed to stand 5 min. and was stirred with an iron rod. The flux was removed without shaking and the clear liquid only poured out on an iron slab. The fluxes of higher melting point were held at higher temperatures.

The solubility in every case was found to be extremely small. Determinations were made only on those fluxes which appeared to have some solubility.

A maximum of 3% Al_2O_3 was obtained with one flux of the following composition: 32.2% NaCl, 42.6 KCl, 15.9 LiCl, 2.8 KF, 0.4 $KHSO_4$, 1.5 organic matter, and with another 30.1% NaCl, 38.4 KCl, 18.9 LiCl, 11 KF, 1.0 LiF, 1.5 AlF_3. Other fluxes dissolved from 0.2% to 1.0% Al_2O_3. Fused borax at 1475° F. dissolved about 2%. These low figures of aluminum solubility are rather surprising when it is considered how often the high solvent power of aluminum fluxes is alleged.

It is considered that the chief effect of aluminum fluxes is a stripping action which results in a suspension of the alumina rather than a solution. While the solubility of alumina in borax is comparatively high, borax raises the melting point and viscosity of fluxes. When anodized aluminum was treated with molten flux, large pieces of oxide film were found in the flux, providing additional evidence of non-solution.

Various colors observed in the fluxes containing alumina were attributed to a fine dispersion of alumina or to colloidal sodium reduced from the melted flux. Apparently most fluxes attack the aluminum, detaching and removing the oxide film as a suspension. The most successful fluxes apparently penetrate the oxide film to react with the basis metal. Mixtures of chlorides and fluorides appear to be better than either chlorides or fluorides alone.

Other Factors

Discontinuities in the aluminum oxide film undoubtedly aid in its removal and hence certain alloying elements may result in easier fluxing, while others (like magnesium) which also form refractory oxides may cause greater difficulty. The continuity of the oxide film on super-purity aluminum may explain in part, at least, the difficulties in welding this material.

It seems almost certain that in most cases, the dehydration, heat crazing, and disruption of the aluminum oxide film (due to differences in coefficient of expansion between the aluminum and the aluminum oxide) of either the natural or artificial variety must occur when heating a piece of aluminum, and that flux should be present at this stage to provide for fluxing. Fluxing at this point might be accomplished more readily than subsequently, when a fresh film has formed.

While unquestionably some light has been thrown on fluxing mechanisms, the investigation thus far has not indicated that any marked improvement over existing fluxes is possible. AUS (2b)

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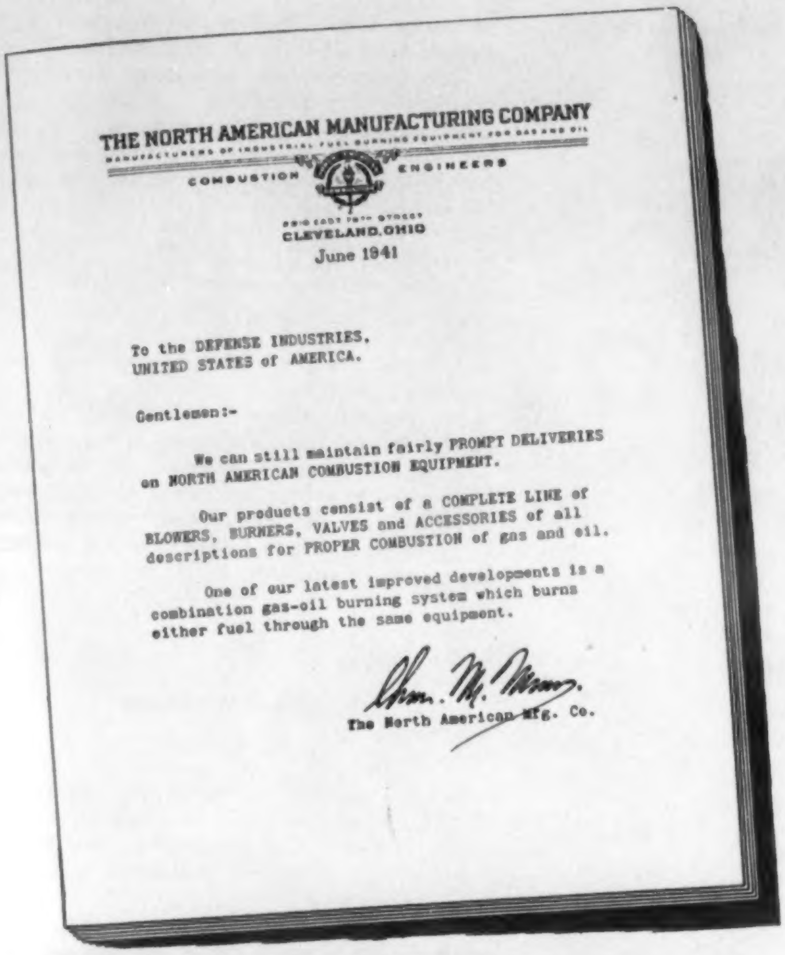

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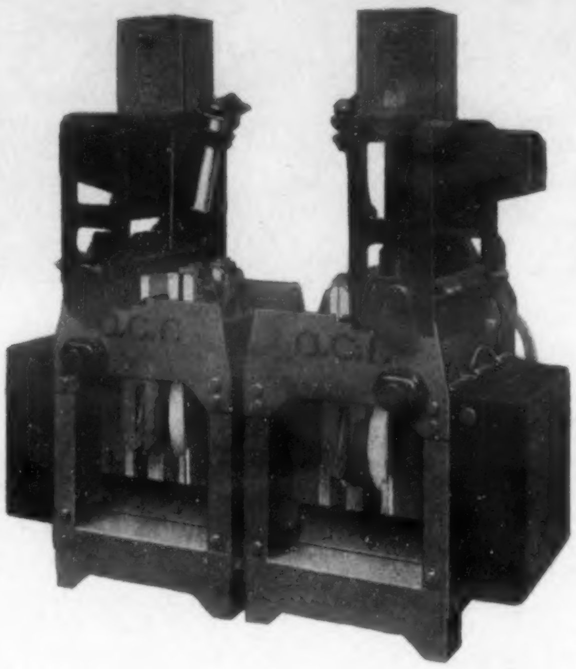

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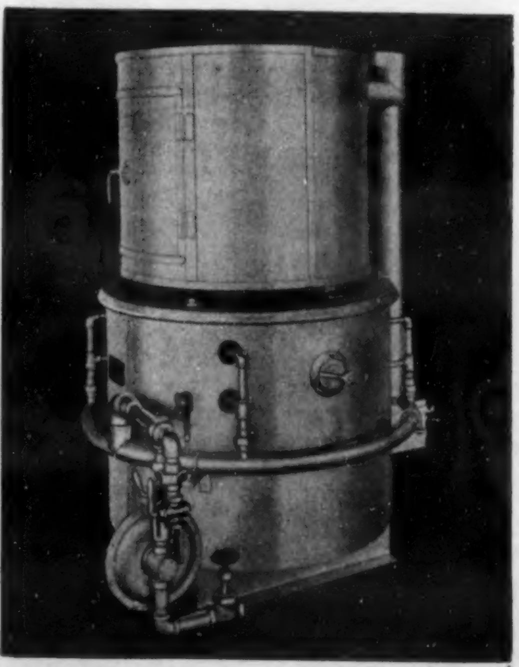

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Contact Corrosion Problems

"PRACTICAL ASPECTS OF CONTACT CORROSION IN METALS." H. SILMAN & A. FREEMAN. *Sheet Metal Inds.*, Vol. 15, Sept. 1941, pp. 1129-1134. Review.

Contact corrosion is really crevice corrosion and may be brought about by contact with non-metallic materials such as glass as well as by contact with metals. *Electrochemical* corrosion, on the other hand, is caused, by a difference in the electrode potentials of the two (or more) metals in contact.

The electrochemical series is a general guide as to the possibility of electrochemical corrosion, but important anomalies appear, due to oxide coatings, overpotential, passivation, etc. Zinc and cadmium are generally anodic to steel and suffer increased corrosion while the steel is protected. Cadmium and aluminum are better protectors than zinc under marine conditions.

Copper is cathodic to steel; therefore, the corrosion of the steel in contact with copper is likely to be increased. Nickel is less harmful. Lead is one of the safest materials for contact with steel.

The behavior of tin-steel couples depends entirely upon service conditions. In the case of coatings, the presence of pores may be much more important than any other individual factor.

Stainless steels are very erratic, possibly because of the wide difference in potential between active stainless steel and the same material when covered with an oxide coating and in the passive condition. Copper-lead cupolas may be used without risk in handling sulphuric, sulphurous, or phosphoric acids.

Nickel is always cathodic to aluminum and their contact should always be avoided. Tin, lead and zinc are generally anodic to nickel. Couples of nickel with such alloys as nickel-copper, nickel-bronze and nickel-brass are variable in behavior depending upon the corroding solution. Monel may be coupled with steel without risk in tap water unless the Monel has a very large surface area in which case the steel will corrode.

Soft solder is anodic to nickel-copper alloys and this combination should always be avoided. Although copper is the most cathodic of all engineering materials except stainless steel, it can be coupled with nickel, lead and tin in mild media.

The behavior of aluminum cannot be predicted very accurately. However, contact between pure aluminum and aluminum-copper alloys such as duralumin generally leads to corrosion of the former. Inhibitive paints should insulate the metals from each other electrically and inhibit direct corrosion of each of the constituent metals in the assembly. Magnesium-base alloys are most susceptible of light alloys to contact corrosion; moreover, rapid attack takes place when the alloy is in contact with aluminum.

In general, copper, nickel and tin are most likely to cause difficulty when coupled with other metals. Metals may be rated from best to worst according to their own susceptibility to acceleration of corrosion by galvanic action as follows: nickel, copper, tin, lead, aluminum, zinc and iron.

JZB (3)

3a. Ferrous

British Cast Irons

A Composite

British engineering experience with cast iron, from the standpoints of specifications and service, is of particular interest to American metallurgical engineers, who are now faced with problems similar to those the British had to solve not so long ago. A group of articles by J. G. Pearce, abstracted below, is, therefore, especially timely.

Specifications

British specifications are discussed in the first article by PEARCE ("British National Specifications for Cast Iron," *Foundry Trade J.*, Vol. 65, July 24, 1941, pp. 59, 60, 64). The establishment in 1928 of the first national specification for general gray iron castings (BSS, 321/1928) was a landmark in the history of cast iron testing. Today there are 6 grades of iron covered in 2 specifications, 321 and 786, ranging from 9,800 to 57,200 lbs./in.^{2} in tension and 5 test-bar sizes in place of the original 3.

Skin-machining of transverse bars gives a better result, and, what is perhaps more important, more consistent results from a series of bars. This may be due to the removal of the stressed skin, especially from green sand molds.

In ordinary engineering irons about 75% of the total deflection is elastic and the remainder is permanent set. These two components enable one to distinguish be-

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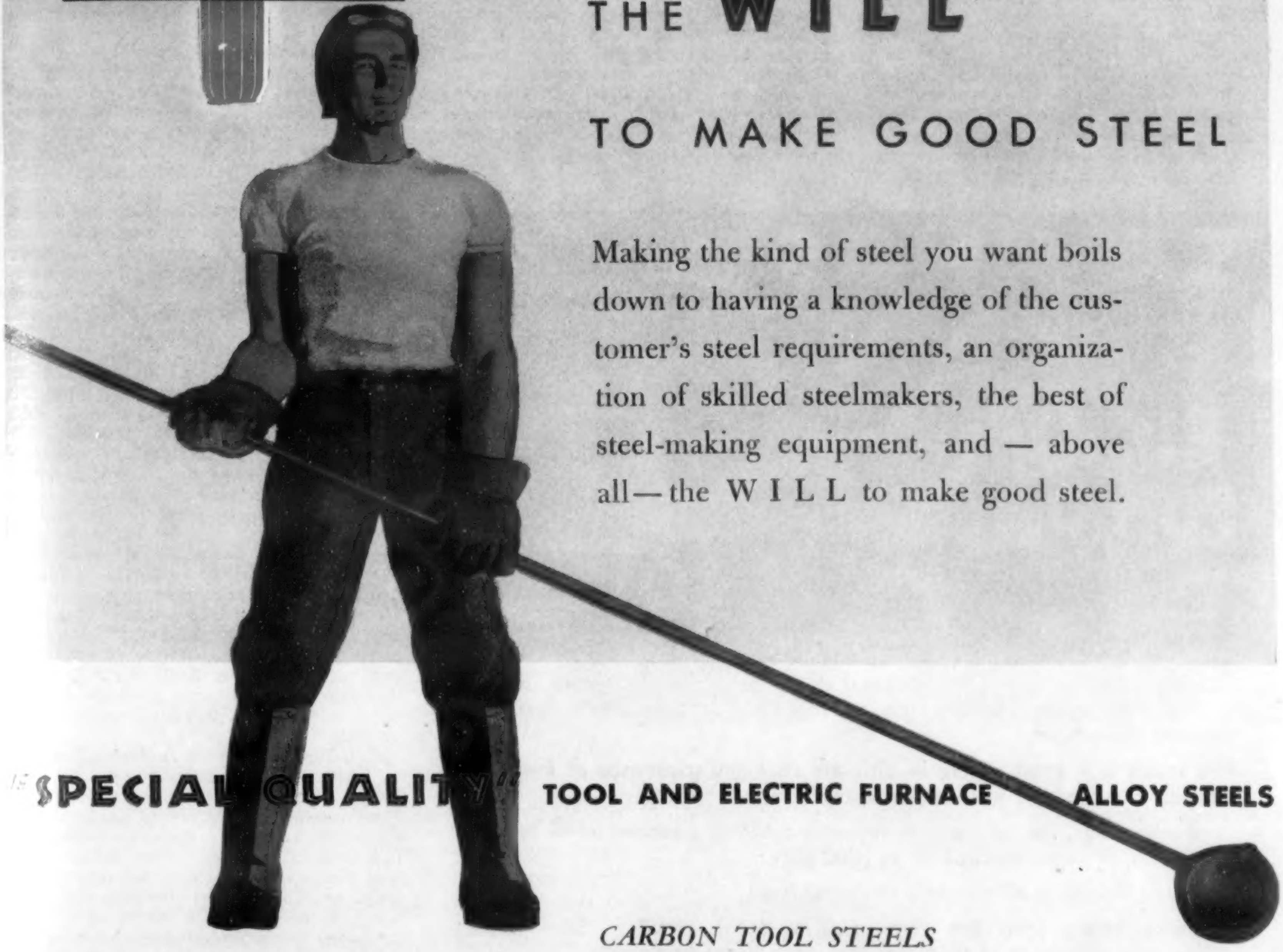

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tween brittle and tough irons, for rigid or brittle irons have a low permanent set, and low resistance to shock. In a soft open-grained iron, the proportion of elastic to total deflection may fall to 60% and in a very rigid iron rise to 90%.

The total deflection increases at a greater rate than the load. The elastic deflection increases at the same rate as the load, or at only a very slightly greater rate. The "high test" iron has a lower deflection per unit of load, but often a greater total deflection.

The superior properties of the high test iron have arisen from reducing the permanent set and thereby enabling greater elastic deflection to take place under load. The total deflection in ordinary comparison may not appear to be greatly changed, but its character is actually materially altered. The significant change is the slope of the deflection line.

The fact that a beam breaking in transverse shows a higher specific stress than the same material broken in tension, constitutes the beam paradox, for in a material so much stronger in compression than in tension, transverse failure, due to a combination of tensile and compressive stresses, must fundamentally be a tensile failure.

There is a reasonably regular relation between tensile and transverse stresses. If the transverse rupture stress is designated R, and the ultimate tensile stress T, both in tons/in.^{2}, the ratio R/T is not constant. From the transverse and tensile strengths obtained, the curve was plotted. This curve is substantially straight in the middle range and slightly curved at the upper and lower ends. The straight portion of this curve has an equation of approximately $R = 1.1 T + 9.5$.

Special Service Irons

The British war effort has awakened a demand for more information on special service irons, to be used not only as substitutes for other materials but in new applications arising out of the new conditions. **Pearce** ("Reports on Special Duty Cast Irons," *Ibid.*, Aug. 21, 1941, pp. 121-122, 126; Aug. 28, 1941, pp. 139-142) attempts to supply the most urgently needed information.

The old visual distinction between cast irons as gray, white and mottled is no longer valid. All cast irons can conveniently be grouped with reference to the presence and form of graphite, and with reference to the structure of the matrix in which the graphite is distributed.

So far as the matrix is concerned, 6 structural groups can be identified, the difference between which are best appreciated from a simplified consideration of the mode of solidification and of the ultimate structure of the metal in the cold. To indicate the effect of structure on properties, the range of Brinell hardness for each group is given as follows: (1) ferritic, 110-140; (2) ferritic-pearlitic, 140-180; (3) pearlitic, 180-350; (4) austenitic, 140-160 (160-220 with chromium); (5) martensitic, soft, 350-450; martensitic, hard, 550-700; (6) cementitic, 280-550. From the engineer-user's point of view, the pearlitic group is by far the largest and most important.

Cast irons can be primarily classified as (a) graphite-free, as in the white cast irons, or (b) graphitic, in which the graphite is in one of the following forms, being chemically and physically the same in all of them: (1) flake graphite, characteristic of gray pig and cast irons; (2) temper carbon nodules, characteristic of malleable cast iron; (3) very finely divided flakes, regularly distributed and variously named, but sometimes called "super-cooled" graphite.

In commercially made structures, graphite is seldom found exclusively in this last form. Although a number of attempts have been made to classify the flake graphite forms in gray iron, the examination of thousands of samples in the British Cast Iron Research Association's laboratories has failed to offer any basis for such classification, or to suggest a relationship with properties going beyond general statements.

[*The A.S.T.M. working with the A.F.A. have lately evolved a sound Recommended Practice, A247-41T, to which readers are referred.*—J. W. B.]

Austenitic Cast Irons

Austenitic cast irons may be regarded as bearing the same relation to ordinary cast irons as some of the stainless steels bear to the ordinary steels. The austenitic cast irons have properties that mark them off as different from all other cast irons, particularly in their softness and ductility; high resistance to wear, erosion, corrosion and heat; non-magnetism and relatively high electrical resistance; low thermal conductivity and high thermal expansion.

Their mechanical properties compare with those of a good engineering cast iron, but their softness and toughness make them readily machinable. They are easily welded. They are not susceptible to ordinary heat treatment, *i.e.* quenching and tempering, but nevertheless, can be annealed at low temperatures with advantage.

They can be cast white if required, and a simple thermal treatment such as annealing at 1750° F. for 30 min. yields a metal with 2-3% elongation in the cold. While the founding of these irons presents special problems, they can be overcome and the

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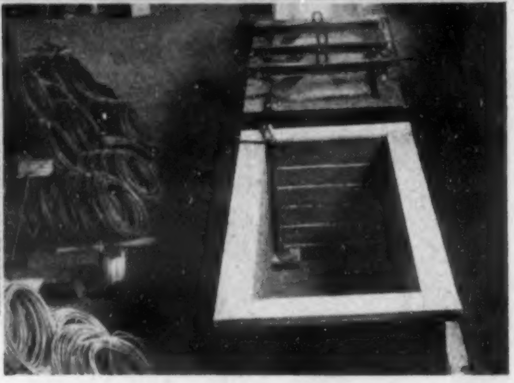

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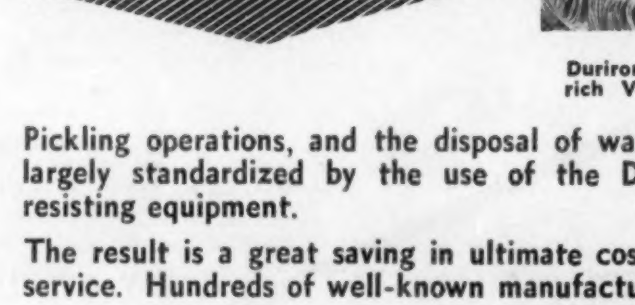

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smallest castings can be successfully made in austenitic irons down to $\frac{1}{8}$ in section. If thin sections should be hard, they can be softened by the treatment given above. They have a specific gravity of 7.2-7.5.

They can be made by the addition of certain alloys to cast iron. Of these, nickel is the most important, and is the only one capable of rendering an iron austenitic without at the same time increasing the carbide content and hence giving an undesirably high proportion of eutectic in the structure. Cast irons of about 3.5% C and over 1% Si become fully austenitic with an addition of 20% or more of nickel.

Copper can be used to some extent to replace nickel and chromium is a convenient means of increasing both the hardness and heat resistance. Irons can be made austenitic by the use of manganese (only $\frac{1}{2}$ as much manganese as nickel being required), but only at the expense of an undesirably high proportion of carbide.

Certain special austenitic irons containing over 30% Ni, such as a 40% Ni, 15% Cr iron, are made for application where low thermal expansions are necessary, and for certain chemical purposes.

Phosphoric Irons

High-phosphorus engineering irons, free from alloying elements, used in the as-cast condition and manufactured in the ordinary way, are discussed in still another article by PEARCE ("Phosphoric High-Duty Irons," *Ibid.*, pp. 105-107). Phosphoric irons are comparatively easily melted and poured, and hence are used for the cheapest and commonest castings. As a consequence, their use tends to be opposed by engineers requiring strong irons.

If phosphorus is present in the iron, a structural constituent appears—a microscopically fine conglomerate into one of the two parts of which phosphorus enters. This constituent is a binary eutectic obtained from what was at solidification a ternary eutectic of gamma-iron, iron carbide and iron phosphide. This loses nearly all of the carbon during the cooling process, the carbide decomposing to iron and graphite, so that as observed under the microscope it is an intimate mixture of iron and iron phosphide.

By controlling the composition of a phosphoric iron, it is possible so to direct the solidification of the phosphide eutectic that the most beneficial (or least harmful) distribution of phosphide results.

The tensile, transverse and fatigue strengths and transverse deflection normally increase uniformly as phosphorus increases, to a maximum at about 0.35% P. As phosphorus increases beyond this pecentage, these values uniformly decrease and for irons containing 0.65% P are about equal to those obtained for phosphorus-free material.

The influence of phosphorus on elastic modulus is not pronounced. The fatigue strength may be expected to follow the tensile strength. The Brinell hardness of plain cast iron increases uniformly with increase in phosphorus content, and a rise of about 4 points may be expected for each 0.1% P. Impact strength diminishes with increase in phosphorus content. Resistance to wear increases with increasing phosphorus.

The phosphide compound is not substantially changed by annealing, and the drop in strength on annealing phosphoric irons is not so pronounced as in the case of nonphosphoric irons. Annealing increases the shock strength. At a given load, the deflection at 1550° F. was less for a phosphoric iron than for any other cast iron tested, not specifically made as a heat-resisting iron. AIK (3a)

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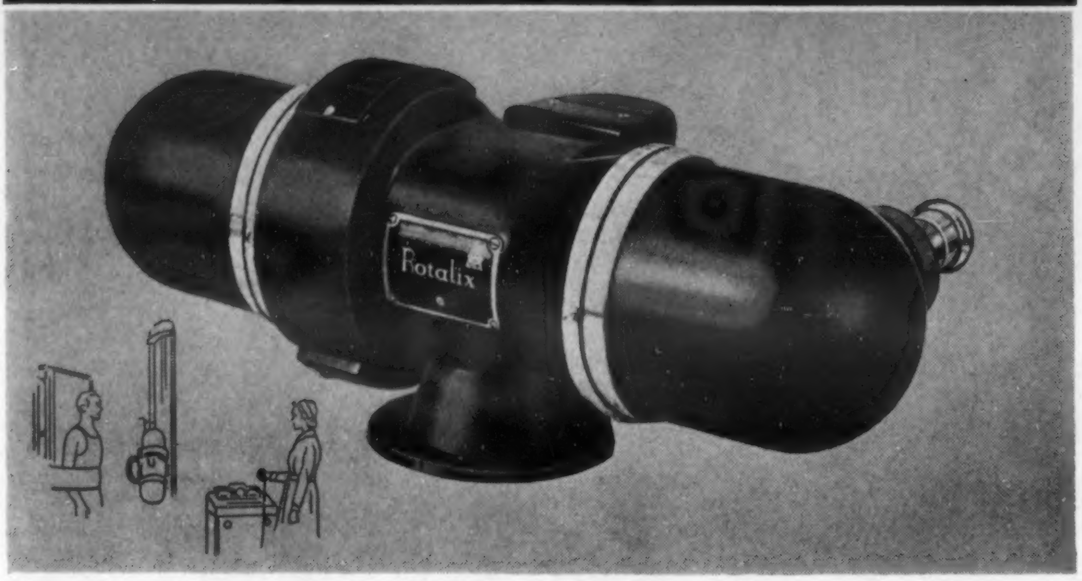

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Cast Iron Piston Rings for Aircraft Engines

"Why Gray Iron Piston Rings for Aircraft Engines?" Paul Lane (Muskegan Piston Ring Co.) *Foundry*, Vol. 69, Aug. 1941, pp. 50-53, 112. Practical.

Although cast iron lacks the toughness of other ferrous alloys, its ability to be cast in suitable shape, and its other really good mechanical properties justify its use for piston rings.

Navy department specification, 49R3a calls for the following limits: 2.10-3.10% Si; under 0.10 S; 0.30-0.80 P; 0.40-0.80 Mn; 2.70-3.20 graphitic C; 0.45-0.75 combined C; Rockwell B 97-104; and Brinell hardness 225-275. When a material of this composition is poured into rings of less than 1/8 in. thickness and weighing 2 oz. each, a material of excellent density, strength and uniform structure is obtained since cooling is very rapid.

The tensile strength is 45,000-50,000 lbs./in.^{2} when they are used as tensile test bars. Modulus of elasticity is about 15,000,000 lbs./in.^{2} Microstructure is of first quality, with abundant precipitation of fine graphite as a result of accelerated cooling. Prevention of free carbides results from close control of raw materials, cupola practice, molding, gating, etc.

Aircraft rings give fairly satisfactory performance from 50,000-100,000 miles. In engines of less than 150 h.p., cast iron cylinders are used while in larger ones steel cylinders are employed.

The steel cylinders are usually forgings that weigh 75 lbs. before, and only 15 lbs. after machining. They are made from plain carbon steel, chrome-molybdenum steel or nitrided steel.

Since the barrels are expensive, wear and abuse on them must be held to a minimum. Thus the ring structure should have suitable wear properties. Large military engines of 1,000 h.p. and over use 5 or 6 rings on each piston. Pistons are of aluminum alloys and differ from automotive pistons in that their diameter often is greater than their length.

Grooves for rings are of 3/32 in. thickness and the spaces between the grooves are limited. Cast iron rings hold groove wear to a minimum. To further retard groove wear, the rings are finished with lapped sides to smoothness of 2-4 microinches.

The aluminum piston is fitted loosely to allow for thermal expansion. Therefore, the rings besides sealing and controlling oil, stabilize the piston in the cylinder.

VSP (3a)

Malleable Iron Bearings

Theory and Practice of Malleable Iron ("Einiges aus Theorie und Praxis des Schwarzgusses") M. Wildermann. *Giesserei*, Vol. 28, May 30, 1941, pp. 252-255. Investigation.

Experiments were made to determine the suitability of malleable cast iron as a bearing metal. It was expected that its bearing properties would be satisfactory because of the presence of free (temper) carbon to act as self-lubrication.

The material used had a ferritic structure, a tensile strength of 57,500 lbs./in.^{2} and an elongation at fracture of 12%. The shaft was an unalloyed carbon steel of 102 Brinell hardness. The peripheral speed could be changed from 3.3-7.3 ft./sec. and the pressure from 85-500 lbs./in.^{2}

The conclusion reached after 6 months

of test was that malleable iron as a bearing metal is good only in cases where the product of pressure x velocity (in English units) is less than 1000; if the product is higher, the malleable iron bushing must be lined with a thin layer of bronze or some other bearing metal.

In actual practice, however, such malleable iron bearings without any lining proved entirely satisfactory in mining and rolling mill operation where peripheral speed is fairly low; the bearing pressure is of little influence.

Only for high velocities *and* high pressures were lined bearings used. Both types are at present in use in large numbers; even after the lining wore off no freezing of the shaft occurred.

Also, in cases of alternating loads the malleable iron bearings were superior to special cast iron, as the fatigue strength of the latter is much lower than that of malleable iron, while the tensile strength of the malleable iron is 35% higher. As machining of malleable iron is much cheaper than that made of steel castings, great savings are claimed to be possible by the use of this material wherever it can replace steel. Ha (3a)

Low-Temperature Toughness of Steel

"Effect of Grain Size and Heat Treatment Upon Impact-Toughness at Low Temperatures of Medium Carbon Forging Steel." Samuel J. Rosenberg & Daniel H. Gagon. *J. Res. Nat. Bur. Standards,* Vol. 27, Aug. 1941, pp. 159-169. Investigation.

The effect of McQuaid-Ehn and austenitic grain sizes at heat treating temperatures and of different heat treatments upon the low-temperature impact-toughness of six heats of S.A.E. 1050 steel was studied. Charpy impact tests, of standard Charpy V-notch specimens, were made at temperatures ranging from +212° F. to —108° F.

Under the specific conditions of test described, the following conclusions appear justified:

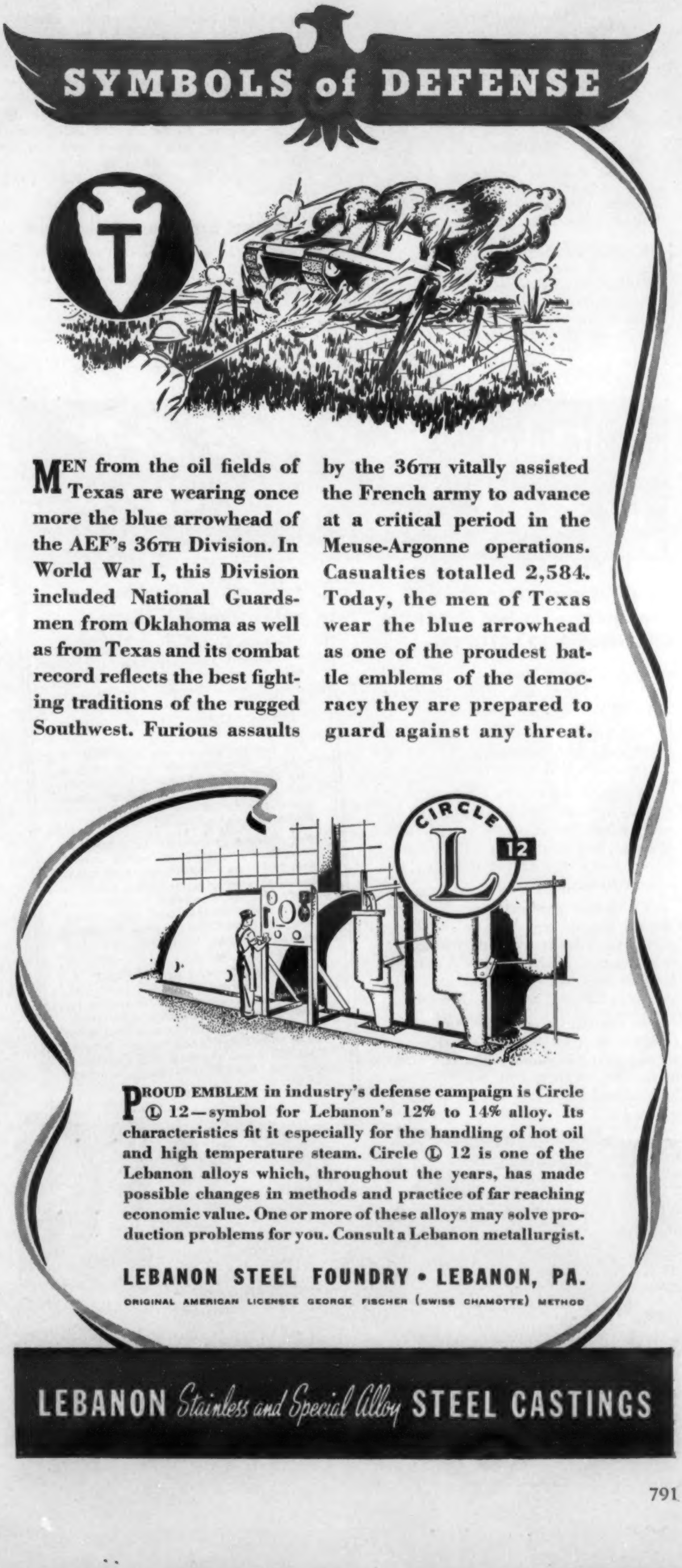
S.A.E. 1050 steel, either as hot-rolled or as normalized, has low impact-toughness. In the hot-rolled condition this type of steel is cold-brittle at room temperature and the transition range to cold-brittleness occurs at temperatures above +212° F. Normalizing the hot-rolled steel improves the impact-toughness at room temperature and above, and the range of temperature at which cold-brittleness occurs is lowered, in some cases, to below +212° F.

Differences in grain size in the normalized steels appear to exert an influence on the impact toughness; the finer the McQuaid-Ehn or the normalized grain size, the lower is the temperature at which cold-brittleness is manifested. This trend was not observed, however, with the hot-rolled steels.

Impact-toughness is markedly improved by hardening and tempering, but normalizing prior to heat treatment has no effect upon this property.

Impact-toughness at room temperature is no criterion of impact-toughness at lower temperatures. Fine grain size, either McQuaid-Ehn or austenitic, is no assurance of impact-toughness superior to that of coarser-grained steel similarly heat-treated (quenched and tempered), particularly as regards the occurrence of cold-brittleness.

S.A.E. 1050 steel, in various conditions of heat treatment, does not have a characteristic resistance to impact in the same sense, for instance, as it has a characteristic tensile strength. Each individual heat, when heat treated, apparently has an inherent resistance to impact between certain limits, and this is dependent upon factors not at present recognized. WAT (3a)



MEN from the oil fields of Texas are wearing once more the blue arrowhead of the AEF's 36TH Division. In World War I, this Division included National Guardsmen from Oklahoma as well as from Texas and its combat record reflects the best fighting traditions of the rugged Southwest. Furious assaults by the 36TH vitally assisted the French army to advance at a critical period in the Meuse-Argonne operations. Casualties totalled 2,584. Today, the men of Texas wear the blue arrowhead as one of the proudest battle emblems of the democracy they are prepared to guard against any threat.

PROUD EMBLEM in industry's defense campaign is Circle Ⓛ 12—symbol for Lebanon's 12% to 14% alloy. Its characteristics fit it especially for the handling of hot oil and high temperature steam. Circle Ⓛ 12 is one of the Lebanon alloys which, throughout the years, has made possible changes in methods and practice of far reaching economic value. One or more of these alloys may solve production problems for you. Consult a Lebanon metallurgist.

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Silver Alloys as Secondary Emitters

"SILVER MAGNESIUM ALLOY AS A SECONDARY ELECTRON EMITTING MATERIAL." V. K. ZWORYKIN, J. E. RUEDY & E. W. PIKE (R.C.A. Lab.) *J. Applied Physics,* Vol. 12, Sept. 1941, pp. 696-697. Experimental.

Alloys of silver containing 1-15% Mg were studied by special methods for determining their properties as secondary electron emitting materials for vacuum tube use.

The amount of magnesium required is not critical but maintaining stability over extended periods of time is difficult since the secondary emission is markedly influenced by the presence and quantity of oxygen in the alloy and in the vacuum tube.

The gain factor in secondary emission may be raised to around 4-6 by induction heating of the alloy in the presence of oxygen. The initial value decreases with time but it is possible to activate the alloy so that the gain will remain constant around 4.3 between 200 and 1200 hrs. The decay is believed to be due to dissociation of MgO in the alloy surface and also to the loss of adsorbed surface oxygen.
HFK (3b)

Thermal Expansion of Chromium

"THERMAL EXPANSION OF CAST AND OF SWAGED CHROMIUM." PETER HIDNERT. *J. Res. Natl. Bur. Standards,* Vol. 27, Aug. 1941, pp. 113-124. Investigation.

The linear thermal expansion of 6 samples of chromium (99.2-96.3%) at various temperatures between −310° F. and 1305° F. was investigated.

The expansion curves indicated anomalies at low temperatures. These anomalies were reversible on heating and cooling. The temperature at which anomalous expansion occurs appears to decrease with decrease in the purity of the chromium.

Hysteresis was not observed on heating cast or swaged chromium to 575° F. and cooling to low temperatures. Exceptionally low average coefficients of expansion were found for temperature ranges in or near the anomalous regions.

The average coefficients of expansion of the samples of chromium from 68° F. to various temperatures between 200° and 1300° lie between 3.2×10^{-6} and 5.7×10^{-6} per °F. (5.7×10^{-6} and 10.3×10^{-6} per °C.).
WAT (3b)

Aluminum-Chromium-Copper Alloys

MAGNETIC INVESTIGATIONS OF THE TERNARY SYSTEM ALUMINUM-CHROMIUM-COPPER ("Magnetische Untersuchungen im Dreistoffsystem Aluminium-Chrom-Kupfer") ADOLF KNAPPWOST & HANS NOWOTNY. *Z. Metallkunde,* Vol. 33, Apr. 1941, pp. 153-157. Original research.

From a practical point of view, the most important finding seems to be the redetermination of the solubility of chromium in copper, which was found to be materially higher than previously found by Fink & Freche (0.77% at 661° C.) and by Hoffmann & Herzer (0.56% Cr at 600° C.). The authors' X-ray tests indicate a solubility of not less than 3.1% Cr in copper at the peritectic temperature.

The authors' endeavor to find ferromagnetic phases in aluminum-chromium-copper alloys in analogy to the well-known Heusler alloys did not succeed. The results of X-ray, microscopic and magnetic tests on alloys up to 70 at. % Cu and 60 at. % Cr are graphically presented.
EF (3b)

Glass-Sealing Alloys

"GLASS TO METAL SEALS II." A. W. HULL, E. E. BURGER & L. NAVIAS (Gen. Elec. Co.) *J. Applied Physics,* Vol. 12, Sept. 1941, pp. 698-707. Experimental.

A continuation of studies on iron-nickel-cobalt glass sealing alloys announced in 1934 is reported.

New sealing alloys are described including "Fernico" (54% Fe, 31 Ni and 15 Co). When pure, this alloy matches 705 AO glass correctly, but the expansion is influenced by small amounts of impurities.

Pure iron-nickel-cobalt alloy, prepared in hydrogen, is ductile and not subject to embrittlement. By expressing both the expansions and transition temperatures of the glass and metal as functions of the composition, the effects of variations in composition on the sealing properties can be computed.

Equations are given for the expansion and the sealing temperature of Fernico with desirable impurities of manganese, silicon and aluminum. The gamma-to-alpha allotropic change in Fernico cannot be induced at any temperature down to that of liquid air but can be produced by cold working.

Three new sealing combinations are described: (a) a 42% Ni iron-base alloy with 1075 glass, (b) a 26% Cr iron-base alloy with 286 glass, and (c) a pure iron with 542 glass. The effect of the oxide bond on the strength of the seal and oxide-free seals are briefly discussed. HFK (3b)

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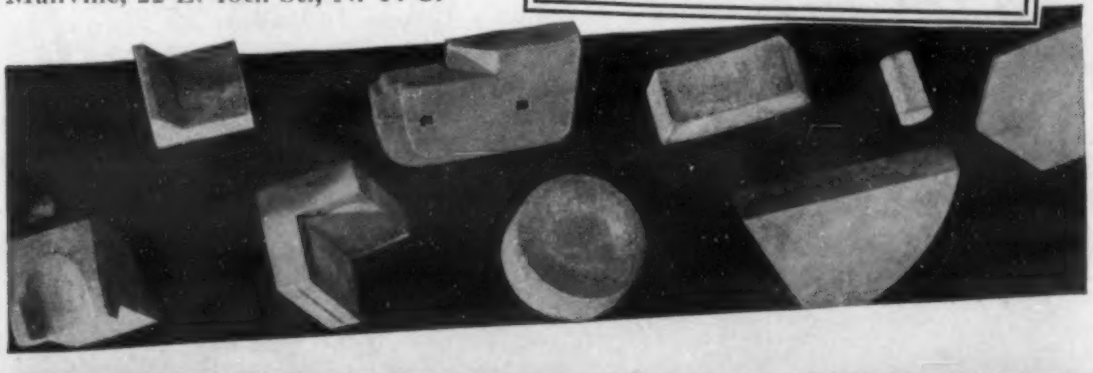

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"Heavy duty" does not adequately describe the severity of tire service on United States Army mobile units. But fortunately for the effectiveness of the Defense Program, destructive operating conditions do not present new problems to our tire producers. Rubber compounders in America have long since turned out truck tires that will meet just such requirements. The tougher the service, the greater the need for zinc oxide in the rubber compound—to provide heat resisting qualities and reinforcement against wear and tear.

Add to the above the fact that zinc oxide is essential in the activation of accelerators of vulcanization, and you have an idea of the importance of this material in the manufacture and performance of tires for Army use. Rubber is just one of at least a dozen major industries which are depending on zinc in one form or another to produce the myriad products pouring into the Defense Program. At the bottom of this page is a partial list of the *rubber* defense items in which zinc pigments are considered indispensable.

The uses for zinc in defense are the same as those in normal times, but the program calls for such quantities of zinc for certain products that non-defense consumers have not been able to obtain all of the zinc they would like to use. This is part of the price that must be paid for national security.

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Steel Hardenability Tests

A Composite

The Society of Automotive Engineers recently held a symposium ("Standardization Sought in Determining Hardenability of Steels—A Symposium." *S.A.E. Journal*, Vol. 49, July 1941, Trans. pp. 266-292) on hardenability tests, the purpose being to effect some sort of standardization as to definitions, tests, procedures and interpretations for the hardenability of steel as a specification-property of automotive steels. The material presented should be useful to metallurgical engineers in other industries as well.

The General Situation

A. L. **Boegehold** of General Motors Corp. discussed "The Use of Hardenability Tests for Selection and Specification of Automotive Steels," (*Ibid.*, pp. 266-276). For any single steel, hardness depends exclusively upon the cooling rate during quenching. A standard hardenability test procedure must furnish the relationship between hardness and cooling rate applicable to a wide variety of steels, section sizes and cooling rates and do it with a minimum amount of work.

Of the various methods proposed for testing hardenability, the Jominy "end-quench" test is best suited for obtaining this fundamental relationship. With the aid of this relationship, it is possible, by substituting cooling rates for corresponding hardnesses, to determine easily the cooling rate at any place in an object of any shape. If the cooling rate is known, the hardness to be expected in that object when made from any steel can be determined by referring to the hardness cooling rate curve for that steel.

For making predictions of hardnesses obtainable in various articles, the information obtained from the Jominy test-bar is arranged as a curve showing relation between cooling rate and hardness (H-CR curve). It is made by substituting cooling-rate values for distances from the quenched end of the test-bar.

In predicting the hardness, the object is made of a low-hardenability steel, quenched in the medium to be used in production, the hardness determined at various points in the cross-section, and the cooling rates corresponding to these hardnesses found by referring to an H-CR curve for the same steel as used for the object.

After deciding what hardness is required in the object, the H-CR curve dictated by the requirement is drawn, and available H-CR curves for a number of steels are examined to see which steels meet it. The cheapest and most machinable of these steels will be selected, unless fatigue tests on the finished part indicate otherwise.

Any change in any of the factors that affect the cooling rate of the object to be quenched requires a redetermination of cooling rates under the new conditions. Any change that affects the hardenability of the steel requires the determination of a new H-CR curve.

The heat treatment and steel used for the object to be studied for cooling rates must be the same as for the Jominy test-bar used to obtain the H-CR curve. In checking the predicted hardnesses with the actual hardnesses obtained, the steel and heat treatment used for the object must be the same as those used to obtain the H-CR curve used for predicting the hardnesses.

The steel selected for objects to be explored for cooling rates should have a continual gradation in hardness over a wide range of cooling rates. Specifications for purchasing steel may be expressed in terms of H-CR values by stating limits, as for example the following minimum and maximum: Rockwell C 28-33 at 30° F./sec. cooling rate, Rockwell C 40-45 at 66°-100° F./sec. cooling rate.

Other types of hardenability test-pieces, such as the Greene specimen [*see below*], can be used for predicting the hardness of an object, provided that the test-bar affords a means of determining the hardness over a certain range of cooling rates, thus furnishing data for plotting an H-CR curve.

For sizes less than ½ in. diam., a test-piece inserted in a sheath of the same shape as the standard test-bar is used. This is an adaptation of the Wuerfel bomb [*see below*] differing in shape of sheath to provide end quenching instead of total immersion. Cooling rates along the insert are determined by substitution for the hardness values on an H-CR curve of the same material tested in a 1 in. round end-quench test-bar.

This method has demonstrated that cooling rates plotted *versus* distance from the quenched end are the same as for standard end-quench bar. Cooling rates in the Wuerfel test may be determined in the same way. It is not necessary to know Grossmann's "severity of quench" factor to predict the performance of steel by the H-CR method.

However, this method is ideal for classifying various quenching media as to severity of quench, because it permits finding how cooling rates are changed in any size or shape bar by changing the quenching medium. It also will be valuable in determining the effect of scale on the hardening of steel.

Hardenability Tests on Small Sizes

The use of the "Wuerfel bomb" for determining hardenability on small sizes is described by F. E. **McCleary** & R. **Wuerfel** of Chrysler Corp. (*Ibid.*, pp. 276-278). The method of determining hardenability of steel by means of a cylinder quenched by immersion is limited by the fact that the test-piece may not have sufficient cross-section to develop the desired series of cooling rates. The Jominy method still requires machining of a special "L" type test-piece for steels of low hardenability.

To remove these limitations, another method has been developed. The bomb used is a conical-shaped piece of steel having a hole concentric with the axis of the cone. The hole is enlarged at the top and threaded to take a plug, which also provides the handle of the assembled bomb. The hole is slightly larger than the test-piece, providing an annular space to be filled with a low-melting alloy such as Wood's metal, which furnishes thermal contact between the bomb and test-piece.

In use, the bomb is warmed above the melting-point of the alloy, the required amount is poured in, the test-piece put in place, and the plug screwed in. The assembly is heated to a temperature suited to the steel under test, quenched in water, warmed to melt the alloy, and the test-piece removed. Hardness readings are taken along the length of the test-piece and used for calculating the "hardenability" as defined by Grossmann and Asimow.

Their procedure for calculating the "critical diameter" gives a rating that may be made common to all other methods. By ascertaining on the test-piece, the position of the 50% martensitic structure and relating it to the critical diameter, a graph may be constructed that correlates longitudinal and cross-sectional positions of equal cooling rate, as determined by the two methods.

Standardization might have been made by direct cooling-rate determination, but as the bomb was designed originally for a small part of the hardenability field, comparative methods seemed sufficient. Results are reproducible within ⅛ in., in terms of the critical diameter.

The space between the test-piece and the hole in the bomb is important, the minimum being about 0.006 in. Spacing of 0.024 in. will vary the critical diameter 3/32 in.

The bomb surface is protected best by nickel plating and heating in a nearly neutral atmosphere. It is important that the

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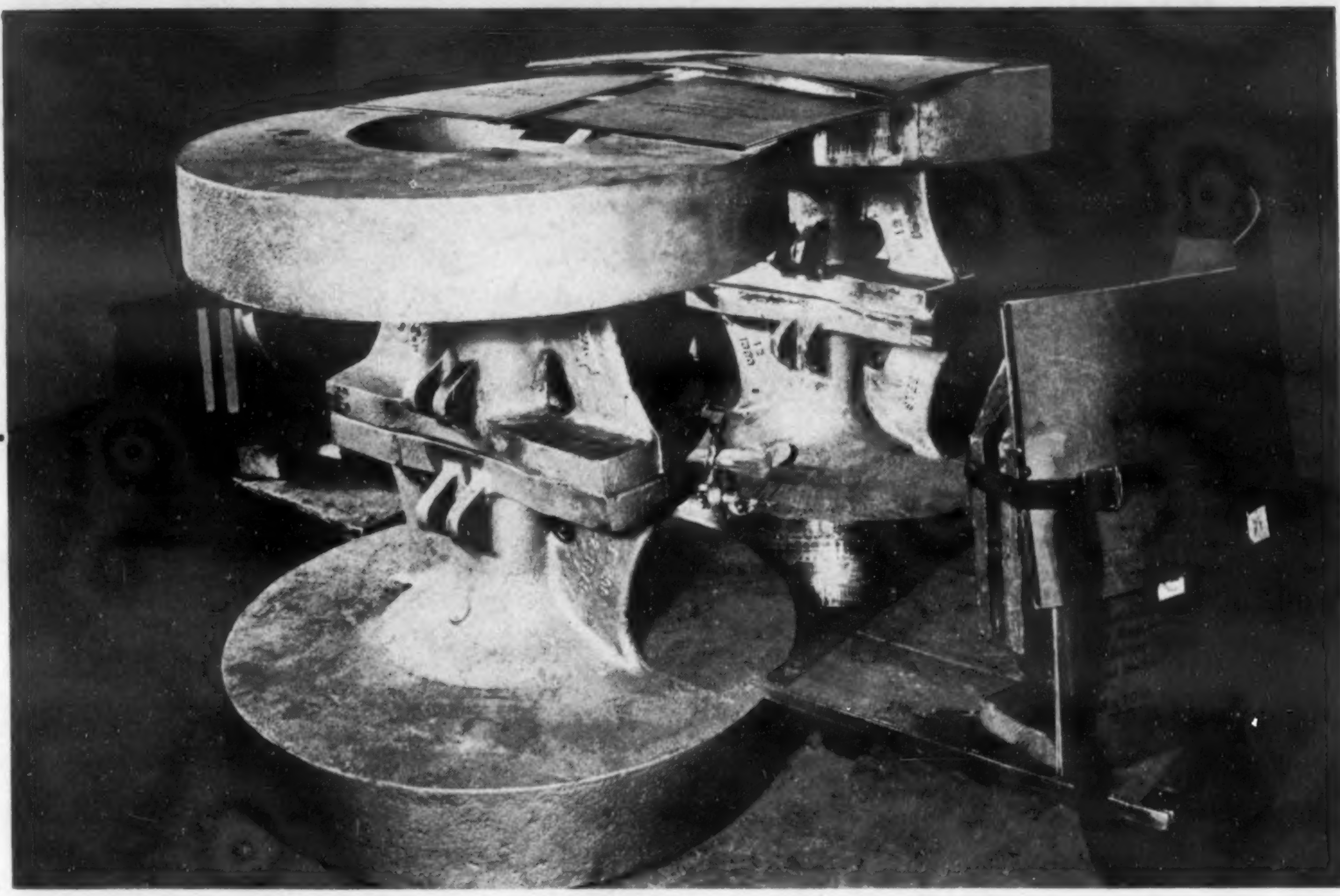

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quench should be constant throughout all related tests and that the maximum hardness characteristic of the steel should be approximated at the small end of the bomb.

Comparison of the Wuerfel method with the two standard procedures shows that the cooling-rate scale opens to a marked degree. The sensitivity of bomb cannot be stated at present.

Shallow-Hardening Steels

The special problem posed by shallow-hardening steels is attacked by O. V. Greene & C. B. Post of Carpenter Steel Co. (*Ibid.*, pp. 278-283). Their test specimen, which incorporates concepts of cooling velocities through a given temperature and of critical bar diameter at a given severity of quench, and which permits correlation of other tests with one another, consists of a tapered round bar having a taper of 1 in. in 5 in.

The specimens used were 5 in. long and ¼ and 1¼ in. in diam. at opposite ends. Test-pieces were heated in a gas-fired semi-muffle furnace containing an atmosphere with about 4% oxygen and 8.2% carbon dioxide, soaked 10 min. at 1450° F., and quenched in a 10% brine solution at room temperature in 3 in. vertical pipe flush, with 1 in. high overflow.

The specimens were ground down to the center section, and Rockwell hardness readings were taken down the center line of the taper test and also on lines normal to the surface. The center section may be etched lightly to show penetration. Reproducibility of test is ± 2 mm. along central axis at the critical hardness point, which is the hardness where the Rockwell hardness changes most rapidly with change in distance.

Some minor disadvantages of this taper test-piece are that a bar at least 1 in. in diam. is required and that the specimen must be split or ground down and kept cool at all times. To overcome the first objection, a modification of the Wuerfel bomb was tried but it was unsatisfactory.

A chart showing the rates of cooling along the longitudinal section of the taper test specimen enables this test to give the specific hardenability in terms of a "critical cooling rate" (in deg. F./sec.) at 1300° F. Comparative study of a series of rounds and taper specimens made from the same steels and treated identically showed that the taper test-piece behaves within experimental error like a series of round bars whose diameters are twice the perpendicular distance from the surface of the taper specimen to any point along the central axis.

This enables the severity of quench to be evaluated by the methods proposed by Grossmann and his associates, and also permits approximate calculations of the penetration to be expected in any given sized round bar. Critical bar diameter may be read directly from either the Rockwell contour down the center axis, or by inspection of the etched case-core pattern obtained on the longitudinal cross-section of the taper test.

Correlation is shown between Shepherd disk Nos. 10-16, "critical cooling rate" (rate necessary to give Rockwell hardness at inflection point of Rockwell contour curve), critical bar diameters at a severity of quench of $H = 4.5$, and "ideal critical bar diameters" for $H = \infty$.

Correlating the Jominy Test with Others

Correlation between the Jominy test and tests on quenched round bars is provided by M. Asimov, W. F. Craig & M. A. Grossmann of Carnegie-Illinois Steel Corp. (*Ibid.*, pp. 283-292). Earlier work has shown that the extent of hardening for any particular steel correlated well with the "half-temperature time" in cooling (the time occupied in the quench, in cooling from the quenching temperature to a temperature half-way down to that of the quenching medium).

Therefore, "half-temperature times" in a Jominy test, when correlated with the "half-temperature times" in quenched bars, should provide a basis for correlation of the hardening in these two forms of test. The position in the Jominy bar that has a certain cooling time should show the same hardness as the position in a round bar that has the same cooling time, when using the same steel.

Comparison can be made by means of charts showing "half-temperature times" and Rockwell C hardnesses against distance from the water-cooled end for Jominy bar, and the same characteristics at various distances from surface to center in a round bar quenched with a known severity of quench.

Investigation of Jominy and round bars for 7 steels showed that hardness values *vs.* "half-temperature times" checked very closely. If one knows the hardness distribution in a Jominy bar, the hardness distribution in any size of bar quenched with any known severity of quench can be predicted by using curves showing the Jominy hardness distribution and "half-temperature times" for Jominy bar and round bars quenched with a known severity of quench.

Hardnesses predicted in this way checked very satisfactorily with actual hardnesses obtained by the direct testing of quenched

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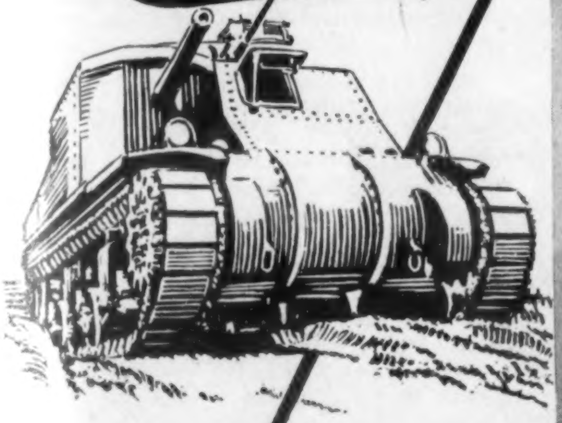

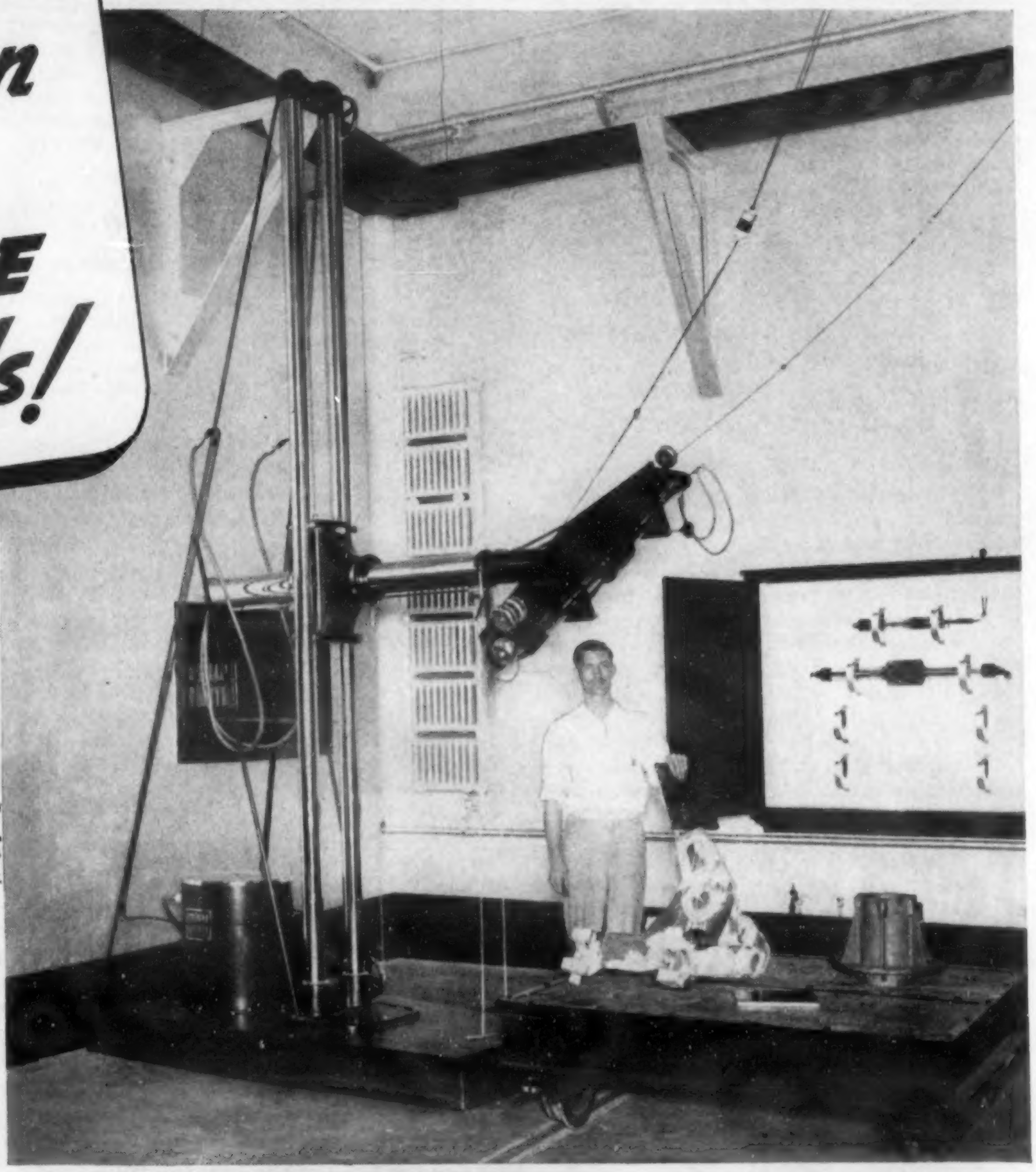

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rounds. If the Jominy distance instead of "half-temperature time" is used for the ordinate in curves showing "half-temperature times" for rounds quenched with a known severity of quench, the predicted hardness can be read directly from these and the Jominy hardness distribution curves.

The "ideal critical size" can be read directly from the Jominy test by using curves showing critical hardness at different carbon contents, Jominy hardness distribution, and correlation between the diameter of round in the ideal quench and the distance from water-cooled end in the Jominy bar. Calculations of "ideal critical size" of round bars agreed very reasonably with those read directly from the Jominy bar. MS (4)

Etching Some Special Alloys

"Etching Technique." M. G. Corson. *Iron Age*, Vol. 148, Aug. 21, 1941, pp. 45-51; Sept. 4, 1941, pp. 56-61. Descriptive review.

Existing etchants may be divided into: (1) Those where the etching effect is due primarily to their content of hydrogen ions; (2) those where etching depends upon hydroxyl ions; and (3) reagents producing differential staining effect—the picrates, ferricyanides, etc.

The etching of nickel and its alloys is difficult. Using ferric chloride dissolved in water, the etched structure of cathode nickel (tensile strength of 85,000 lbs./in.^{2}, hardness of 180 Brinell) at 100 and 500 diameters showed a black streak as the boundary between the starting sheet and the heavier part of the cathode.

This cathode was cold rolled 50% into strips. Then it was annealed at 1475° F. In another test, the cathode was annealed at 1475° F. without cold rolling; it recrystallized completely.

For commercial nickel (nickel that had been treated with carbon and magnesium) a good representation of grain size was obtained at 100 diameters, although black spots were evident in the grains and along their boundaries. This probably was caused by graphite or magnesium oxide, which became enlarged in etching with ferric chloride. Neutral ferric chloride in aqueous solutions forms a good etchant for this class of work, although this is not true for high-chromium nickel-base alloys.

Again, with copper-beryllium alloys, the accepted point of maximum solubility is 2.1% Be at 1117° F. Industrial alloys run from 2.0 to 2.5% Be. With 2.5% Be, the alloy contains some beta grainlets. When the beryllium content drops to 1.85%, however, homogenization can be obtained.

Wrought copper alloys containing beryllium above 1.8% usually develop small grains. Quenched from about 1475° F. and etched, they show clean grains of alpha with a few beta grainlets here and there. Chill cast ingot with only 1.05% Be, etched with ammonium persulphate and magnified at 100 and 500 diameters, showed a few undissolved grainlets of beta and the usual dendrites.

There is also a spontaneously formed precipitate. Among this are found fine wavy lines, called "veining," "etching effect," etc. When the ingot is hot worked and quenched from 1650° F. (to obtain large grains) and a sample etched with ammonium persulphate, the veins show definite directions and less definite ramifications in each grain. They also have a tendency to pass from one grain into another, and to abruptly change directions when so doing.

Ammonium persulphate produces the same type of veining in all copper base alphas that are subject to precipitation hardening. No such veining can be produced, however, in brasses with either 20 or 34% Zn. Nor is it possible to produce veining in cupro-nickels and alpha aluminum bronzes.

When etching copper alloys, the persulphate solution is preferred. If merely beautiful pictures with polyhedral grains and twin bands sharply defined are to be obtained, the older reagents that act by virtue of chlorine or hydroxyl ions can be used. VSP (4)

Defects in Light Metal Castings

Non-Destructive Testing of Light Metal Castings ("Zerstörungsfreie Prüfverfahren für Leichtmetallguss") G. Kraetsch & A. Scheck. *Aluminium*, Vol. 23, May 1941, pp. 239-246. Practical.

While surface defects and holes, blisters, oxide inclusions, etc. in light metal castings can be detected comparatively easily by visual and microscopic examination, gamma rays or X-ray inspection, radiography is often expensive or inconvenient for routine work. In its place, especially for the detection of micro-fissures, the oil boiling test is more convenient, although dirty and requiring much time.

The piece is boiled in oil at 320° F. for ½ hr., the oil is then removed by sawdust or blowing with compressed air, and the piece is dipped in a mixture of alcohol and whiting or of carbon tetrachloride and talc, or it is sand-blasted. The defects show up very clearly on the surface where the oil retained in the seams, cracks, etc. is absorbed by the chalk or talc.

An entirely new method was developed by the I. G. Farbenindustrie in which the piece is pickled for 10-30 sec. in 20% nitric acid. In this treatment, magnesium alloy castings assume a fine, white surface on which the defects of surface and pipes can clearly be seen. Ha (4)

Vacuum Furnace for Grain Size Test

"Use of a Vacuum Furnace for the Direct Determination of Austenite Grain Size in Steel." E. G. Shumovskii. *Zavodskaya Laboratoriya*, Vol. 10, Mar. 1941, pp. 268-271. In Russian. Research.

Comparative determination was made of the austenite grain size in steel by the McQuaid-Ehn, isothermal and oxidation methods and also by direct observation with a Reichert microscope in a vacuum furnace.

In the isothermal method the specimens were carburized in the same mixture as in the McQuaid-Ehn method for 2 hrs. at 1725° F. after which the temperature was reduced to 1325° F. At this temperature the specimens were kept for 10 min. and then dipped in water at room temperature.

In the oxidation method the specimens were placed in the electric furnace at 1725° F. and were kept at that temperature for 1 hr., during which they were subjected to the oxidizing atmosphere of the furnace. The specimens were then dipped in water at room temperature. The McQuaid-Ehn method was followed in strict accordance with the A.S.T.M. standards.

The grain sizes as determined by the McQuaid-Ehn method were the largest, the isothermal method gave medium size, and the oxidation method the smallest size. The method of direct observation in a vacuum furnace gave the "true sizes" and also made it possible to follow the tendency of the grain to grow.

The time required for each determination is shown as follows:

Method	*Time*
Oxidation	1-2 hrs.
Isothermal	3-4 hrs.
McQuaid-Ehn	at least 12 hrs.
Vacuum	
To create vacuum	1.5 hrs.
To raise temperature above AC_3	1.5 hrs.
To form boundaries between grains	2.0 hrs.
	5.0 hrs.

The necessity of special apparatus and the difficulty of creating a high vacuum at temperatures above 1300° F. limit the method to research only. BZK (4)

The Electron Microscope

"Surface Studies with the Electron Microscope." V. K. Zworykin & E. G. Ramberg (R.C.A. Lab.) *J. Applied Physics*, Vol. 12, Sept. 1941, pp. 692-695. Experimental.

An experimental technique is described in which the surface structure of a metal surface is reproduced in a collodion replica film which in turn is examined in an electron transmission microscope.

A layer of metal is evaporated in vacuum upon the metal surface studied to considerable thickness or is further thickened by electroplating. This layer is stripped from the metal surface mechanically and coated with a solution of collodion in amyl acetate. After drying the metal film is removed by solution in a suitable reagent leaving a thin collodion replica film which is then placed upon a fine mesh supporting screen for examination in the electron microscope.

Examples are given of electron pictures taken at 20,000 X of such replica films removed from steels with typical Bainite and pearlite structures. An advantage of this method is that the relief height of constituents in the metal surface has a corresponding density in the electron picture.

The replica film may also be obtained by applying collodion directly to the metal surface and stripping off the film but due to the attendant distortion of the film such replicas are of inferior quality. HFK (4)

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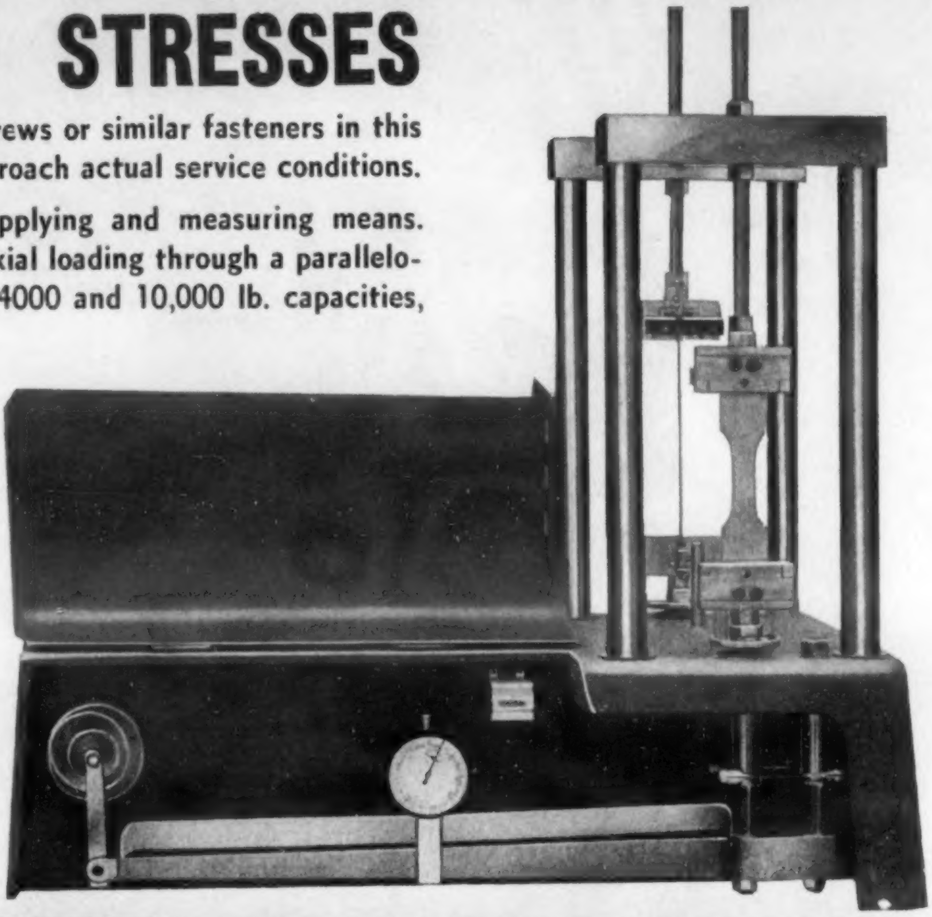

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Baruch on Industrial Mobilization

AMERICAN INDUSTRY IN THE WAR. *By Bernard M. Baruch. Published by Prentice-Hall, Inc., New York, 1941. Cloth, 6¼ x 9¼ in., 498 pages. Price $5.00.*

Baruch, head of the War Industries Board in the World War, has constantly urged that the principles then worked out, by trial and error, for industrial mobilization be utilized in a plan that could be put in force immediately on the advent of emergency. Then years ago he presented such a program to the War Policies Commission. The plan is discussed in reference to present conditions in this book, but present conditions have not required much modification.

Vital in the system suggested by Baruch are the freezing of all prices and wages ("we must stabilize all prices or no price") and the appointment of a "single responsible head for action," who may use "committees for counsel," but in whom is vested *both* responsibility and authority.

Unwillingness to delegate authority and the desire to tie the labor vote so firmly to the present administration that the latter may continuously perpetuate itself or at least name its own successors, have so far frustrated the following of the logical Baruch pattern. As Ironpants Johnson says in his forward "the new planless pattern is gradually being brought back and draped on the proved pegs of the old. It is being brought back by the clutch of circumstance and the pressure of necessity."

The administration talks a serious situation, but it doesn't act it. Individual understanding, which applied *en masse* might force the administration to action in line with its own words, will be fostered by reading the book.

For metallurgical engineers chapters 2, 3 and 4, on iron and steel, copper and brass, and other metals, hold the greatest interest. Although we have forgotten it, priorities were applied, rationing of non-defense industry was resorted to, and entire elimination of some raw materials from non-defense use was made. The 1918 automobile production was cut to a quarter of that of 1917. No platinum could be used in jewelry.

The official prices of 23½ cents per lb. for copper, 12 cents for zinc, 70 cents for tin, 33 cents for aluminum, 8 cents for lead, and $250 per ton for ferromanganese sound odd in comparison to present prices. Only that for nickel, 35 cents per lb. has a familiar ring.

It was found that warehouses and storerooms contained heavy stocks that had been accumulated in private hands, strikes badly hampered the program, and there was governmental muddling in the early days of the 1917-1918 war. Order began to come out of chaos as experience was gained and as public opinion grew stronger, more willing to endure hardships in its determination to win the war.

Baruch's book brings out the ineptness of the present administration in declining to profit by past experience, but it offers hope that the cold logic of circumstance will tardily lead to sound action. The publication of the book may be a factor in making it a little less tardy, but the voice of experience is not listened to by New Dealers, who apparently have to make their own mistakes. It is to be hoped that they make them fast and get them out of their systems.

—H. W. GILLETT

Spectrographic Analysis

THE SPECTROCHEMICAL ANALYSIS OF METALS AND ALLOYS. *By F. Twyman. Published by Chemical Publishing Co., Inc., Brooklyn, N. Y., 1941. Cloth, 6 x 8¾ in., 355 pages. Price $8.50.*

Many persons who use spectrographic methods of analysis nowadays are doubtless unaware of the great debt they owe Frank Twyman, Fellow of the Royal Society, and managing director of Adam Hilger, Ltd., of London. The book under review is only one of many contributions which Mr. Twyman has made to the literature of spectrochemical analysis. Of even greater importance are his contributions to the implementation of spectroscopy and spectrography, since he is responsible for the basic designs of many, if not most, of the various types of prism spectrographs which have come into standard use during the past 30 yrs.

Twyman's latest book was written primarily to meet the needs of the metallurgist or engineer who wishes to acquaint himself with methods of spectrochemical analysis as they are used in industrial laboratories. Twyman is peculiarly fitted to write on this subject as a result of his long experience in the design and production of spectrographic equipment, and his association over the years with the development of new methods of spectrochemical analysis.

The book includes chapters on the history of the development of spectrochemical analysis; spectrographs and accessory apparatus, the microphotometer; methods of exciting emission spectra; taking spectrograms and identifying elements, with lists of books and tables; techniques of spectrochemical analysis; problems to which spectrochemical analysis is applicable; the practice of spectrochemical analysis of metals and alloys; and the analysis of substances not in metallic form, including gases. In addition, there is a chapter by A. C. Candler on the elements of atomic spectrum theory.

The book is filled with a wealth of material on methods of analyzing for various specific elements, such as aluminum, copper, gold, lead, and ferrous materials. One of its outstanding features is the wealth of reference material given, enabling the reader who is interested in pursuing any subject to find quickly references giving more detailed information.

It is to be regretted that the author did not, in his chapter on spectrographs and accessory apparatus, go more fully into the details of spectrographic equipment and the usefulness of apparatus and different types, since it is doubtful if anyone in the world could speak more authoritatively on this subject. Twyman seems to the reviewer to have leaned over backward in this chapter in his attempt to avoid placing undue emphasis on apparatus with whose design and production he has been closely associated.

Visual spectroscopic methods, for example, are given less than half a page; their increasing importance would seem to justify more. Three pages are quoted verbatim from an article by the reviewer on the advantages and disadvantages of the diffraction grating; the advantages and disadvantages of prism instruments are not mentioned except by inference, their general acceptance being taken for granted.

The present book will fill a much-felt need among users of spectrographic equipment, particularly those in industrial and metallurgical laboratories. Over many years the writings of Twyman and his colleagues constituted much of the literature of practical spectrographic analysis, and it is fortunate indeed that he has now been able to make available in the present book more of the fruits of his wide experience in spectrographic techniques.

—GEORGE R. HARRISON

ANNOUNCING

T January 1942 "Annual Review Issue" of METALS AND ALLOYS

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trends

By Edwin F. Cone, Editor

Hardening by Induction

The heating time for hardening crankshafts is reported to have been cut from 12 hrs. to less than 5 min. by 2,000-cycle inductive heating at the Chicago tractor plant of the International Harvester Co. Involving five different sizes and types of shafts for Diesel and gasoline engines, this method is stated to have simplified balancing, obviated the normal pickling process and increased core toughness. With this installation, first licensed by the Ohio Crankshaft Co., more than 2,000,000 shafts have been so produced without a rejection for incorrect hardness.

Transmutation of Metals

Scientists are still at work on the transmutation of metals. The transmutation of mercury into a new type of gold that gives off radiations like radium, a transmutation which creates a new element that combines the properties of nature's two most precious metals, was recently described before the American Physical Society by two Harvard University professors. The transmutation of mercury into platinum by the same process was also reported. Interesting scientifically, but of little value in quantities producible.

Zinc Production

The country's output of zinc is on the increase. A report submitted at the annual meeting of the American Zinc Institute states that by 1942 about 1,000,000 tons will be produced. The output has expanded from 478,000 tons in 1938 to an all-time record of 724,000 tons in 1940. The increased demand is due to Defense and Aid-to-Britain needs.

Rail Output

The production of steel rails by American producers, at 1,678,986 net tons last year, was the largest since the 2,098,021 tons in 1930. Over 97 per cent of the total last year was made in open-hearth furnaces. Alloy steel rails at only 172 tons in 1940 was the lowest in many years. These data are from the American Iron and Steel Institute.

Saving Vital Metals

The Western Electric Co. announces a saving by the Bell System of more than 5,000,000 lbs. of metal vital to defense needs this year, including enough aluminum to build more than 275 fighter planes. The substituting of materials in 1941 will divert for use in defense work nearly 1,700,000 lbs. of aluminum, almost 667,000 lbs. of nickel, well over 3,000,000 lbs. of zinc and 8,300 lbs. of magnesium —all made possible by long-range planning, research and readjustment in manufacturing.

For example, 65 tons of aluminum are saved annually by replacing aluminum with steel in the "finger wheel" in dial telephones. The use of zinc is being substantially reduced by coating much of the hardware used on telephone pole lines with lead instead of galvanizing. Less zinc is also being used in production of new phones.

Saving Zinc

One large brass company has discontinued the manufacture of one of its high-zinc types of brass pipe to conserve zinc for National Defense. Pure copper or 85 Cu 15 Zn pipe will handle the applications in which the normally available and cheaper high zinc brass pipe has been used.

It is estimated that if all manufacturers of brass pipe would adopt this policy, additional zinc at the rate of about 8,000,000 lbs. a year will become available for metals vital to the Defense Program.

Steel Welding Wire

A new record in the production of welding wire was made in 1940, according to the American Iron and Steel Institute. A total of 238,795,000 lbs. was made last year, an increase of 30 per cent over the 1939 output of 183,436,000 lbs., then a record. This increase certainly demonstrates the wider use of welding processes in construction of many kinds, in shipbuilding and in other applications. Further evidence of this trend is the statement that the output of welding wire rose 989 per cent between 1932 and 1940. By contrast the gain in the steel ingot production in that same period was 442 per cent.

"Scrambled Technology"

The trend in technical and trade magazine articles of mixing indiscriminately advertisements with authors' discussions does not abate. In some journals this (to us) offense is on the increase. It is not comfortable nor is it conducive to concentration to start reading an article and on turning a page to be confronted with a double-spread advertising page of something entirely unrelated. We have always regarded this as "scrambled technology."

Profit Sharing

A trend which we think might laudably be emulated, is announced by the Rochester Lead Works, Rochester, N. Y. Employees of this company have begun participation in a semi-annual apportionment of the net profits of the corporation. A percentage of the net profits will be divided on a basis of each employee's earning capacity.

(Additional "Trends" on page 806)

★

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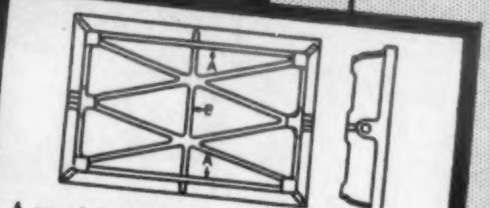

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Cincinnati, Ohio	Cincinnati Grinders Incorporated
Cincinnati, Ohio	The Cincinnati Milling Machine Co.
Cleveland, Ohio	Fulton Foundry & Machine Co.
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Pittsburgh, Pa.	Meehanite Metal Corporation
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trends

By *Edwin F. Cone, Editor*

Larger Airplanes

Airplanes larger, and with a passenger carrying capacity equal to transatlantic liners, are foreseen by Igor I. Sikorsky, of the United Aircraft Corp., in an address before the Hartford Chapter of the A. S. T. E. Already in the blueprint stage are planes that will fly to Europe in 10 hrs. and some that will be able to carry a full load of bombs to Europe or the Orient and return. This means a still greater demand for metals and alloys.

Higher Steel Wages

Wages of steel workers in the American steel industry have expanded 50 per cent over those prevailing in 1929, according to *Steel Facts* for September, published by the American Iron and Steel Institute. These wages now average 98c per hr. as against 65c only 12 yrs. ago. By contrast steel prices in the same period have risen only an average of 2 per cent.

Selenium

The demand and use of selenium are on the increase. A vice president of the International Telephone & Radio Mfg. Corp. states that he estimates his requirements of ultra-refined selenium may be 10,000 lbs. monthly next year compared with only 1,500 lbs. per month at present. The absolutely pure metal is required in electric current rectifiers as selenium rectifiers. Selenium is found in copper ore from which it is refined. Years ago it was tossed on the slag piles.

Pig Iron and Ferroalloys

Production of pig iron and ferroalloys by American furnaces, blast and electric, expanded in volume during the first half of this year. The rate was 4,570,000 net tons per month to July 1, 1941, against about 3,950,000 tons each month for all of 1940. This is a gain of about 16 per cent

Our Steel Expansion

In a pamphlet—"Steel for Defense"—the American Iron and Steel Institute tells in a few words the extent of the expansion of the American steel industry. The plants of this industry can now produce "86,000,000 net tons of steel a year and this is 70 per cent more steel than was consumed during the peak year of World War I, and 35 per cent more than was taken in 1929, the peak year of peace time."

The United States can make nearly as much steel as all the rest of the world together. During 1940, about 42,500,000 tons were produced by Germany and by all the other countries of continental Europe excluding the U.S.S.R.

The U.S.S.R. and England made about 21,800,000 and 15,000,000 tons respectively with about 13,200,000 tons made by other countries, mostly by Japan and Canada.

Ferromanganese

The production of this vital material is increasing beyond all previous records. The output from blast furnaces to Sept. this year, has been at the rate of 50,520 net tons per month with 57,710 tons made in July, the peak month thus far. This year's volume compares with 31,110 tons per month for all of 1940 with 46,260 tons in March last year, the highest.

Bauxite

A new survey by the Bureau of Mines shows that domestic production of bauxite, the ore from which aluminum is derived, could be multiplied rapidly if necessary. About 60 per cent of the supply is now imported from Dutch Guiana. Domestic output this year is running about 50 per cent higher than in 1940. Should shipping not be available, the load could be shifted on to American producers with little or no delay.

X-ray Study

There are now a half-dozen 1,000,000-volt X-ray equipments in use in six of the leading plants of this country. This is in strong contrast to the number in use only a few years ago. The plants in which the present equipment is in use are: General Electric Co., Schenectady, N. Y.; American Steel Foundries; Babcock & Wilcox; Combustion Engineering; Ford Motor Co.; and two naval yards. The examination of metals and their alloys is an outstanding feature of their use.

Aircraft Valve Steels

Two decades ago aircraft engine valves lasted 50 to 100 hrs. in service, unless a rush of cold air during a sideslip warped them and "conked" the engine, it is reliably asserted. Today the valves of a 400 mile-an-hour plane are built to operate at a temperature of 1,600 deg. F. and they last for as many as 4,000 hrs. of flying, despite the severe corrosive effect of modern, high-test aviation fuel.

Better steel makes this performance possible—a nickel-chromium steel, originally for automobile engines and later further developed for airplane use.

(Additional "Trends" on page 804)

Metals and Alloys

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THE MAGAZINE OF METALLURGICAL ENGINEERING

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DECEMBER 1941

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